RESEARCH & DEVELOPMENT

Research and Technical Support for NCDOT Strategic Prioritization

Volume 1: Development of Peak Average Daily Traffic (PADT) Factors and Data Extrapolation for P4.0
Volume 2: Summary of Peak Average Daily Traffic (PADT) Factor Work for P5.0

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16. Abstract

Volume 1 of this report presents methodologies for: 1) the development of Peak Average Daily Traffic (PADT) factors, 2) the development of default PADT factors for North Carolina, and 3) the extrapolation of known and default PADT factors to provide statewide coverage. PADT provides a measure of seasonal variability and peak loads that cannot be captured by AADT alone and may be suitable to supplement or replace conventional AADT in the strategic prioritization process. The goal was to develop PADT factors suitable to supplement the conventional AADT in NCDOT's P4.0 prioritization effort for state-maintained highways (primary and secondary routes) in 2015, and to further expand the count coverage and application of PADT for P5.0 by 2017. The development of the methodologies was based on traffic volume data collected from continuous and seasonal coverage count locations in North Carolina and resulted in the calculation of known and default PADT factors for four different route classes (Interstate, US, NC, and secondary routes) that account for urban and rural area type.

Volume 2 of this report summarizes the PADT factor work for the interstate system and for North Carolina counties with limited or no data for generating PADT factors. The objective of this effort was to develop a plan for enhancing coverage counts and analytics for prioritization P5.0 and beyond. The primary components of this effort include 1) an evaluation of HERE.com sensor data for use in producing PADT factors for I-540 in the Triangle region, 2) calculation of PADT factors for interstates from HERE.com, sample, and continuous counts, 3) an update of interstate default PADT factors, 4) application of the interstate sampling plan to generate system-wide PADT factors using interpolation and extrapolation, and 5) a sampling plan for North Carolina counties with limited or no data for generating PADT factors to be implemented in 2017.

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EXECUTIVE SUMMARY

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Volume 1: Development of Peak Average Daily Traffic (PADT) Factors and Data Extrapolation for P4.0

INTRODUCTION

Annual average daily traffic (AADT) is one of several statistics that transportation agencies use to report roadway volumes. However, high traffic volumes are often concentrated over short and specific time periods due to seasonal activities, such as tourism, vacation, or holiday-related travel. To understand and address seasonal traffic volume fluctuations without excessive investment, an additional measure to aid in traffic volume analysis beyond AADT can add value to the prioritization process. Such a metric would allow transportation agencies to enhance their strategic plans and ensure accurate prioritization for the construction and maintenance of critical roadways.

This report presents methodologies for: 1) the development of Peak Average Daily Traffic (PADT) factors, 2) the development of default PADT factors, and 3) the extrapolation of known and default PADT factors. PADT provides a measure of seasonal variability and peak loads that cannot be captured by AADT alone and may be suitable to supplement or replace conventional AADT in the strategic prioritization process. The goal was to develop PADT factors suitable to supplement the conventional AADT in NCDOT's P4.0 prioritization process for state-maintained highways (primary and secondary routes) in 2015, and to further expand the count coverage and application of PADT for P5.0 by 2017. The premise of the PADT concept is that a facility may have sustained peaking characteristics related to seasonal activities, e.g., beach traffic in the summer, and that this seasonal variability is not fully represented in the traditional method of calculating an overall annual average traffic load value through the AADT. As a result, the volume-to-capacity (v/c) ratio calculated from AADT will not accurately reflect peak loads with higher v/c ratios for certain time periods of the year, and especially for transportation facilities that are subject to high seasonal variability in traffic loads. Investment and improvement decisions based on an average annual value may fail to reflect these peak load characteristics.

Both statistical and geographic information system (GIS) analyses were conducted to calculate, apply, and extrapolate known and default PADT factors generated from traffic volume data from statewide continuous and seasonal coverage count stations provided by the North Carolina Department of Transportation (NCDOT).

LITERATURE REVIEW

A review of the literature shows that, while many State DOTs employ seasonal adjustment factors derived from continuous counts to adjust coverage counts to AADT volumes, a separate factor for determining and evaluating seasonal and peak loads that supplements AADT has not been widely explored. The methodology used by state highway agencies to adjust coverage counts into estimates of AADT is provided by the Federal Highway Administration (FHWA) in their Traffic Monitoring Guide (TMG) (*1*). The TMG instructs that coverage counts for a year be adjusted by seasonal factors derived from continuous counts from the same year, but does not provide a method for seasonal weighting of AADT.

The Minnesota Department of Transportation (MnDOT) uses seasonal adjustment factors based on data collected from over 70 automatic traffic recorders (ATRs) to adjust short duration counts to AADT volumes (*2*). The factors are derived from all continuous count data collected for a year, with missing data supplemented with data from the previous year. The factors account for month of the year fluctuations, the effects of weekend traffic, and urban/rural area type, and they are used to adjust short duration 48-hour counts collected on weekdays (Monday-Friday) in the months from April-November to AADT volumes. But, again, no seasonal AADT factor is defined.

The Montana Department of Transportation (MDOT) also uses seasonal adjustment factors to adjust short duration counts to AADT volumes (*3*). The factors for a given year are three-year averages and they account for the operational characteristics of a facility, month of the year fluctuations, the effects of weekend traffic, and urban/rural area type.

Similarly to the MDOT, the Ohio Department of Transportation (ODOT) uses seasonal adjustment factors to adjust short duration counts to AADT volumes based on three-year averages that account for roadway functional classification, month of year fluctuations, weekend traffic patterns, and urban/rural area type (*4*). The ODOT is careful to note that their seasonal adjustment factors are not applicable for locations near major generators that experience atypical traffic patterns, including recreational areas, theme parks, and shopping centers.

The Florida Department of Transportation (FDOT) uses seasonal adjustment factors based on data collected from 278 permanent traffic counters, known as telemetered traffic monitoring sites (TTMSs), to adjust short duration counts from over 4,000 coverage count stations to AADT volumes (*5*). The factors account for month and week of year fluctuations. The FDOT also calculates a Peak Season Conversion Factor (PSCF) that is used to average weekday daily traffic to the Peak Season Weekday Average Daily Traffic (PSWADT), which is an estimate of the average weekday daily traffic during peak season for a facility used for urban traffic modeling and forecasting.

While a survey of all State DOTs' use of seasonal adjustment factors is beyond the scope of this report, it is evident that it is an established practice to transform coverage count data into a more accurate estimation of AADT based on temporal, functional, and contextual factors. Across the surveyed state agencies and FHWA, seasonal factors are used exclusively to adjust short-duration counts and account for seasonal variability. However, none of the agencies appear to use a seasonally-weighted AADT to reflect peak loads due to tourism or other seasonal trends. The calculation and use of a separate factor for understanding and addressing peak seasonal traffic patterns appears to be a unique concept and a novel approach in project prioritization.

METHODOLOGY

PADT Factor Calculation

Traffic data were provided by NCDOT for 71 permanent traffic count stations and 3,676 seasonal coverage traffic count stations across North Carolina. The count stations are located on roadways categorized based on four route class types (Interstate, US, NC, or secondary routes). A GIS file was also provided with the geographic location of the stations, as well as supplementary data for each station that included route classification, route description, area type (urban or rural), number of lanes, speed limit, and other attributes.

PADT factors for continuous count data are conceptually different from PADT factors for coverage count data, since the former are derived from a year's worth of *continuous* count data at select locations, while the latter are based on a sample or 4 or 5 weeks during the year.

As a first step, the FHWA Annual Average Daily Traffic (AADT) estimation method was adopted, particularly since it can be used to overcome isolated days of missing traffic data resulting from the use of an automatic traffic data collection environment. The AADT of the continuous count stations was calculated using the following equation (*1*):

$$\text{AADT} = \frac{1}{7}\sum_{i=1}^{7}[\frac{1}{12}\sum_{j=1}^{12}(\frac{1}{n}\sum_{k=1}^{n} VOL_{ijk})]$$

Where,

VOL = daily traffic for day k, of day of the week i, and month j,

i = day of the week,

j = month of the year,

k = the occurrence order number of day of the week, and

n = the number of days of that day of the week during that month.

For seasonal coverage count stations, AADT was calculated depending on the number of weeks with valid data using the following equation:

$$AADT = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{1}{7}\sum_{i=1}^{7} VOL_{ij}\right)$$

Where,

VOL = daily traffic for day i and week j,

i = day of the week,

j = data collection week of the year,

n = the valid number of data collection weeks.

Continuous count data were provided for one year (2013). Almost all stations showed a few missing data entries, and data from the previous year were substituted whenever a period of missing data was substantial, such as a month of missing data. In cases where only a day or two of data were missing, the data gaps were not expected to affect the analysis results using the AADT estimation method recommended in the FHWA Traffic Monitoring Guide (*1*).

For the seasonal coverage count data, all locations did not have the same amount of data, meaning there were variations in the number of weeks or days being counted for traffic volume. The number of data collection weeks varied from 1 to 10 in the overall dataset. A majority of count stations (80.1%) had five weeks of data collection followed by four weeks of data collection (9.7%). The research team did not use locations having less than four weeks of data because they did not represent an adequate sample of counts across the year. The seasonal coverage count data were collected from 1999 to 2013, with the specific data collection year varying by station. The research team identified a small number of locations that had seasonal coverage count data collected in two different years. In those cases, the team used the more recent year of data as long as the location provided the minimum amount of daily traffic count data necessary for PADT factor calculation.

PADT factors for the 71 continuous count stations were initially estimated using four different methods developed for this effort. These methods were tested and compared before determining a final recommended method for continuous count data. Conceptually, the PADT factor is calculated by dividing the highest day(s) of traffic by the average traffic load. In other words, the PADT factor is a ratio that describes how much higher the peak load is compared to the volume of an average day. For example, a PADT factor of 1.3 would indicate that the peak load is 30% higher than that estimated from an average day. The PADT factor will be greater than 1.0 in months with seasonal increases in traffic over the annual average, and will be less than 1.0 in months with seasonal decreases relative to the annual average. A facility without much seasonal variability is expected to have a PADT factor close to 1.0 throughout the year.

Four different PADT factor estimation methods were tested and compared as follows:

Fac_1: the one highest daily traffic load divided by AADT

Fac_12: the average of the 12 highest daily traffic loads divided by AADT

Fac_30: the average of the 30 highest daily traffic loads divided by AADT

Fac_month: the highest monthly average daily traffic load divided by AADT

"Fac_1" always results in the highest (or equal to the highest) PADT factor, since it divides the single highest traffic day of the year by the annual average. However, this factor is expected to be highly sensitive to isolated outlier days and therefore unreliable in a prioritization process. The "Fac_12" and "Fac_30" estimates are expected to be successively lower, as more days are included to first estimate an average peak load before dividing by the AADT. These measures are expected to be more stable and representative than the single day "Fac_1." However, one drawback of all three aforementioned approaches is that they do not consider consecutive peak loads, but rather evaluate the overall 1, 12, or 30 highest days of the year – even if the days are scattered across multiple weeks and months.

As such, the "Fac_month" factor was introduced to focus on the single highest month of the year. The research team generally preferred this factor, as it allows for the most direct interpretation of the results. Stations with resulting high PADT factors could be scrutinized based on which month showed the peak load and categorized based on a hypothesized major traffic generators, such as "beach traffic" for summer months or "fall leaf season" in the North Carolina mountains for fall months. This sort of categorization is not as directly apparent for the initial three factors.

The authors also considered the use of a fifth factor that would calculate the 30 highest consecutive days. However, the comparison of the four initial factors showed that the general trends were consistent across all four, and this fifth factor was not expected to produce any different results or patterns. Ultimately, the highest month factor was preferred over the highest 30 consecutive days, because it more readily allows for interpretation of the results relative to the monthly calendar and seasonal characteristics of different regions in the state.

PADT factors for the seasonal coverage count stations were estimated using two slightly different methods, SPEC and MAX, based on different threshold levels for treating missing data. The SPEC method applied a more stringent filtering criterion to arrive at a more conservative dataset, while the MAX method was used to maximize the number of locations available for data analysis (yet still filtering those locations with incomplete data). As a result, the SPEC method resulted in a total of 2,658 valid locations while the MAX method had 3,204 locations. After analyzing the distribution of the additional data resulting from the MAX method, the research team determined that the MAX method is equally reliable compared to the SPEC method, while also providing a significant advantage by offering 20% more data.

PADT factor calculation details for all count data, as well as the specifics of how missing data were handled between the SPEC and MAX methods, can be found in Appendix A. The PADT factors for the 3,204 MAX method locations was obtained as follows:

$$Fac\_week = \frac{\text{Highest Weekly ADT}}{\text{AADT}}$$

PADT Factor Calculation Results

Tables 1 and 2 present summary statistics of the PADT factor calculation results for continuous and seasonal coverage count data, respectively. The tables show the sample sizes of count stations and the percentage of stations with a PADT factor greater than 1.2. The tables also show the overall average and the average after removing outlier sites. The outliers were those sites outside of the 95th percentile confidence interval. The average after removing outliers is considered a more stable estimate.

Table 1 PADT Factor Calculation Results for Continuous Count Stations

Route Type	Observed Count			Value (PADT Factor)			
	Total	PADT Factor >1.2	Percent of PADT Factor >1.2	Average	Average Without Outliers	Upper bound of 95th Percentile CI	Maximum (Month)
Interstate-Urban	7	0	0 %	1.07	1.06	1.14	1.15 (Jul)
Interstate-Rural	6	3	50 %	1.20	1.20	1.30	1.26 (Jul)
US-Urban	9	2	22 %	1.13	1.09	1.45	1.50 (Jul)
US-Rural	18	5	28 %	1.15	1.12	1.42	1.56 (Jul)
NC-Urban	2	0	0 %	1.09	1.09	1.13	1.11 (Apr)
NC-Rural	5	1	20 %	1.24	1.10	1.82	1.84 (Jul)
Secondary-Urban	12	2	17 %	1.13	1.09	1.43	1.57 (Jul)
Secondary-Rural	8	1	13 %	1.12	1.09	1.26	1.29 (May)

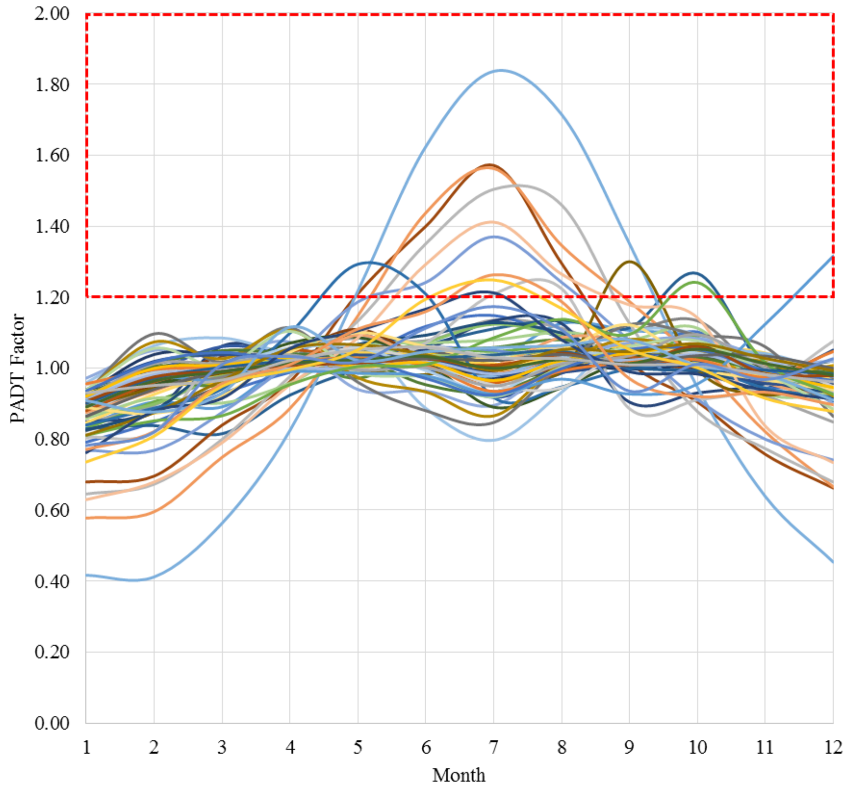
Table 2 PADT Factor Calculation Results for Seasonal Coverage Count Stations

Route Type	Observed Count			Value (PADT Factor)			
	Total	PADT Factor >1.2	Percent of PADT Factor >1.2	Average	Average Without Outliers	Upper Bound of 95th Percentile CI	Maximum (Month)
Interstate-Urban	8	0	0 %	1.07	1.09	1.17	1.19 (Jul)
Interstate-Rural	3	0	0 %	1.14	1.14	1.24	1.20 (Sep)
US-Urban	521	23	4 %	1.07	1.06	1.22	1.60 (Feb)
US-Rural	553	72	13 %	1.12	1.10	1.35	2.17 (Jun)
NC-Urban	392	36	9 %	1.09	1.07	1.30	1.88 (May)
NC-Rural	760	79	10 %	1.10	1.09	1.32	2.38 (Jun)
Secondary-Urban	398	28	7 %	1.09	1.07	1.31	2.14 (Jul)
Secondary-Rural	569	68	12 %	1.12	1.10	1.38	2.96 (Feb)

For continuous count data, the 'Fac_month' factor most directly represents monthly seasonal effects of PADT. Figure 1 is a plot of the PADT factor values by the 'Fac_month' method separated by month of the year (1=January, 12=December) for all 71 stations. In general, a station with little seasonal variability is expected to show PADT factors close to 1.0 throughout the year. In contrast, stations with high seasonal variability are expected to show high PADT factors during peak months, and concurrently low PADT factors in off-peak months.

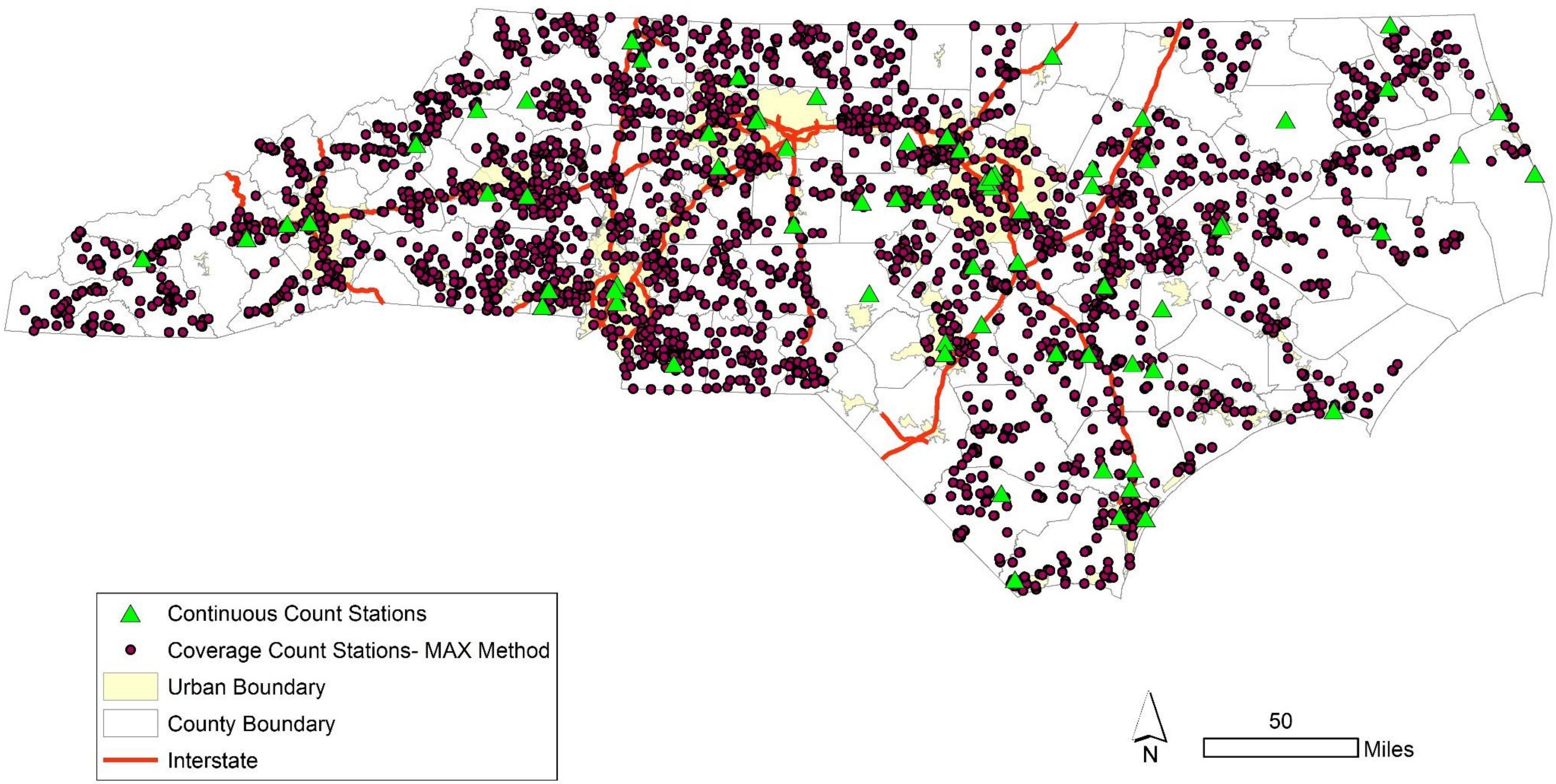
The research team postulated an initial criterion in the level of PADT to identify critical sites. A PADT factor greater than 1.2 was established as a threshold, above which the PADT results significantly differed from the conventional AADT approach. The region of PADT above 1.2 (20% increase in peak load over AADT) is represented as a dashed box in Figure 1 and tends to peak during summer months, suggesting a primary impact from travel and tourism.

Figure 1 PADT Factor Values for Continuous Count Stations by Month of Year



For seasonal coverage count data, the 'Fac_week' factor most directly estimates monthly seasonal effects of PADT in the absence of an entire year's worth of count data. As provided in Table 2, the average value of the PADT factor for each route type by area type was slightly lower than the PADT factor results from the continuous count data. This was expected due to the increased number of sites and decreased number of samples per site (from 12 per year to 4-6 per year). A comparison of continuous and seasonal coverage count locations is provided in Figure 2. Across all continuous and seasonal coverage count locations, however, the research team observed that rural areas had higher PADT factor values than urban areas, particularly for US and NC routes.

Figure 2 Continuous and Seasonal Coverage Count Locations



PADT Default Factor Calculation

Based on the results from PADT factor calculation for continuous and seasonal coverage count data, default PADT factors were developed for Interstate, US, NC, and SR routes. Interstate roadway segments were classified by Average Annual Daily Traffic (AADT) level, and US, NC, and SR segments were classified by area type (urban or rural) and AADT level. The AADT for Interstate segments was found to account for urban versus rural differences, so area type classification was found to be unnecessary for these routes.

Upper boundary, lower boundary, and middle range AADT thresholds for Interstate routes were determined by an analysis of data trends and natural breakpoints in the continuous count data. Interstate continuous count locations included the 13 stations described in the PADT factor calculation methodology, as well as an additional 13 stations provided by NCDOT. Table 3 presents the proposed AADT thresholds for Interstate routes. Table 4 provides the sample sizes of the PADT factors by AADT level for the calculation of Interstate default PADT factors.

Table 3 Interstate AADT Threshold Values

Route Type	Low AADT	Middle Range AADT	High AADT
Interstate	<20,000	20,000-60,000	>60,000

Table 4 Sample Size of PADT Factors by AADT Level for Calculation of Interstate Defaults

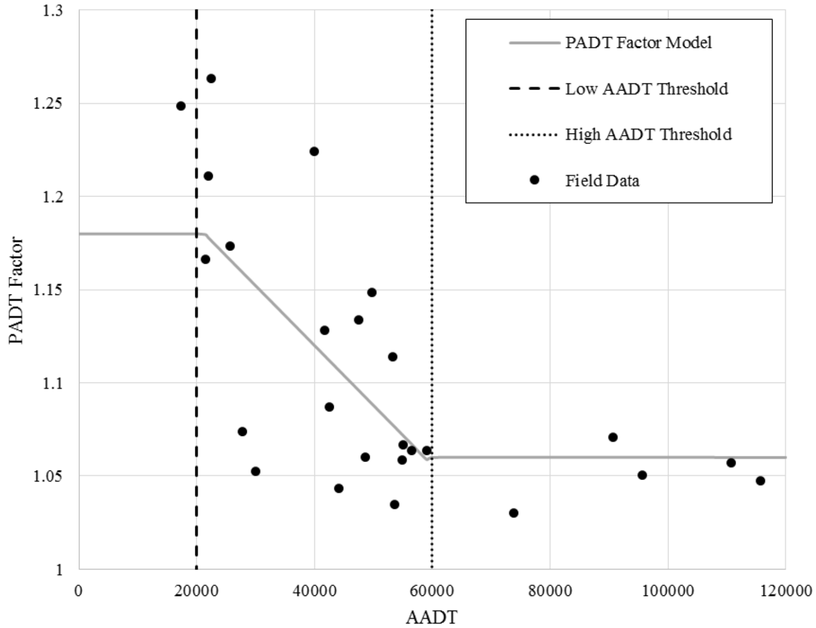
Route Type	Low AADT	Middle Range AADT	High AADT
Interstate	2	19	5

A linear regression equation that estimates the PADT factor from AADT was generated using the middle range AADT values from the continuous count data provided by NCDOT. The dependent variable was the PADT factor for the 19 continuous count stations in the middle range calculated based on the 'Fac_month' methodology as previously detailed. Default PADT factor values for middle range AADTs were estimated from the resulting equation shown in Table 5. For segments with AADTs outside the middle range, an upper boundary default PADT factor was assigned to high AADT values, and a lower boundary default PADT factor was assigned to low AADT values. A graphical representation of this three-regime model is shown in Figure 3, along with the field-measured PADT values.

Table 5 Recommended PADT Default Factors by AADT Level for Interstate Routes

Route Type	Low AADT	Middle Range AADT	High AADT
Interstate	1.18	Varies from 1.06 to 1.18 based on the following equation: 1.248507+(-0.00000321*AADT)	1.06

Figure 3 Interstate PADT Factor Model as a Function of AADT



Threshold values for US, NC, and SR routes were determined by the 50th percentile of traffic volumes by route type and setting for seasonal coverage count stations located on the routes, and confirmed by an analysis of data trends and natural breakpoints in the seasonal coverage count data. Table 6 presents the proposed AADT thresholds for US, NC, and SR routes by setting. AADTs below the given value were classified as low AADTs and AADTs above or equal to the threshold were considered high AADTs. The sample sizes used for the calculation of the default PADT factors for US, NC, and SR routes are provided in Table 7. Recommended default PADT factors by setting and AADT level for US, NC, and SR routes are provided in Table 8.

Table 6 AADT Threshold Values by Type and Setting for US, NC, and SR Routes

Route Type	Urban Locations	Rural Locations
US Route	15,500	6,500
NC Route	10,500	3,500
SR Route	5,500	1,000

Table 7 Sample Size of PADT Factors by Type, Setting, and AADT Level for Calculation of US, NC, and SR Route Defaults

Route Type	Urban Locations		Rural Locations		Total Sample Size
	Low AADT	High AADT	Low AADT	High AADT	
US Route	266	255	271	282	1,074
NC Route	192	200	399	361	1,152
SR Route	192	206	286	283	967

Table 8 Recommended Default PADT Factors by Setting and AADT Level for US, NC, and SR Routes

Route Type	Urban Locations		Rural Locations	
	Low AADT	High AADT	Low AADT	High AADT
US Route	1.06	1.05	1.09	1.07
NC Route	1.07	1.05	1.09	1.07
SR Route	1.07	1.06	1.11	1.08

Data Extrapolation

A GIS layer, STA_T3, was provided by NCDOT that contained points representing traffic monitoring stations used for generating 2013 AADTs. An additional GIS layer, SEG_T3, was provided that contained line segments representing all state-maintained roadways assigned the AADT from the associated traffic monitoring station in the point GIS layer. There were 24,808 features in each GIS layer with a one to one relationship between them. Both files were based on the linear referencing system arcs for the first quarter of 2014, 2014 Q1 LRS Arcs.

In general, the extrapolation of known and default PADT factors was accomplished with the following steps:

1. Attribute STA_T3 station points with route type and urban/rural area type using NCDOT's 2015 Q1 Road Characteristics GIS layer by applying a spatial join in ArcGIS
2. Transfer these attributes to the SEG_T3 line segments by applying a spatial join in ArcGIS
3. Use these attributes and the provided 2013 AADT to assign default PADT factors to segments
4. Assign continuous and sample based PADT factors to the segments (non-default factors)
5. Fill in missing non-default factors on the primary routes (where continuous and coverage stations are available)

Specific data extrapolation procedures performed in ArcGIS are included in Appendix B.

Data extrapolation, or "gap-filling," for Interstate routes was conducted using the known PADT factors calculated for 25 continuous and four seasonal coverage count station locations. The known PADT factor for a continuous or seasonal coverage count station location was assigned to the nearest traffic monitoring station segment in SEG_T3. The known PADT factors were then applied to adjacent Interstate route segments in both directions until one of the following three conditions was encountered:

1. an intersection with a different Interstate route,
2. an intersection with a US route, or
3. an urban/rural boundary.

A total of 109 out of the 607 Interstate route segments in SEG_T3 were assigned PADT factors based on known PADT factors. This total includes the 29 segments with known PADT factors and the 80 segments that have extrapolated PADT factors. Default factors are recommended for the remaining 498 segments that could not be applied known PADT factors through the extrapolation method.

Data extrapolation for US routes was conducted through a similar process, using the known PADT factors calculated for 1,065 seasonal coverage count station locations in the T3 dataset. The known PADT factors were applied to the nearest US route segments using a spatial join based on the route name (Rte_Nm) that was assigned from NCDOT's 2015 Q1 Road Characteristics shape file. These preliminary results were refined to ensure that the extrapolation was limited by the following three conditions:

1. an intersection with an Interstate route,
2. an intersection with another US route, or
3. an urban/rural boundary.

Extrapolation was also limited at locations where the dominant flow of traffic appeared to be interrupted by a signalized or stop sign controlled intersection with any route type. A total of 3,692 out of the 5,082 US Route segments in SEG_T3 were assigned PADT factors based on known PADT factors. This total includes the 1,065 segments with known PADT factors and the 2,627 segments that have extrapolated PADT factors. Default factors are recommended for the remaining 1,389 segments that could not be applied known PADT factors through the extrapolation method.

Using the same method for US routes, data extrapolation for NC routes was conducted using the known PADT factors for 1,134 seasonal coverage count station locations included in the T3 dataset. The known PADT factors were applied to the nearest NC route segments in SEG_T3 using a spatial join based on the route name (Rte_Nm) that was assigned from NCDOT's 2015 Q1 Road Characteristics shape file. The results were refined to so that the extrapolation was limited by the following conditions:

1. an intersection with an Interstate route,
2. an intersection with a US route,
3. an intersection with another NC route, or
4. an urban/rural boundary.

Similarly to US routes, extrapolation was also limited at locations where the dominant flow of traffic appeared to be interrupted by a signalized or stop sign controlled intersection with any route type. A total of 3,621 out of the 6,018 NC route segments in SEG_T3 were assigned PADT factors based on known PADT factors. This total includes the 1,134 segments with known PADT factors and 2,487 segments that have extrapolated PADT factors. Default factors are recommended for the remaining 2,397 segments that could not be applied known PADT factors through the extrapolation method.

For SR routes, no extrapolation was conducted beyond assigning known PADT factors to their respective stations in the T3 dataset. A total of 585 segments have known PADT factors, and default factors are recommended for the remaining 12,473 segments.

A summary of the T3 sample sizes for Interstate routes can be found in Tables 9 and 11. A summary of the T3 sample sizes for US, NC, and SR routes in Tables 10 and 11.

Table 9 Number of T3 Segments for Interstate Routes by AADT

Route Type	Low AADT	Middle Range AADT	High AADT	Total Sample Size
Interstate	87	291	229	607

Table 10 Number of T3 Segments for US, NC, and SR Routes by Setting and AADT

Route Type	Urban Locations		Rural Locations		Total Sample Size
	Low AADT	High AADT	Low AADT	High AADT	
US Route	1,524	1,316	1,244	997	5,081
NC Route	1,108	1,336	2,013	1,561	6,018
SR Route	3,745	4,442	1,839	3,032	13,058

Table 11 Number of T3 Segments for Interstate, US, NC, and SR Routes by PADT Factor Type

Route Type	Known PADT	Extrapolated	Default Only	Total
Interstate	29	80	498	607
US Route	1,065	2,627	1,389	5,081
NC Route	1,134	2,487	2,397	6,018
SR Route	585	0	12,473	13,058
Total	2,813	5,194	16,757	24,764

A total of 44 segments in the T3 dataset could not be assigned default or extrapolated factors due to their route designations. Two of these segments are designated as RMP routes, and 42 are designated FED routes per NCDOT's 2015 Q1 Road Characteristics shape file. One of the RMP segments (1300027) has a record in the dataset, but no feature exists for the record. The FED segments appear to be located on Fort Bragg in Cumberland County. The excluded segments are visualized in Figure 5.

Known and extrapolated PADT factors are the recommended PADT factors where values are available. Recommended PADT factors for all other route segments are the default factors summarized previously in Tables 5 and 8. Known and extrapolated PADT factors for all routes are visualized in Figure 4, and recommended PADT factors are visualized in Figure 6.

Figure 4 Known PADT Locations and Extrapolated PADT Factors for All Routes

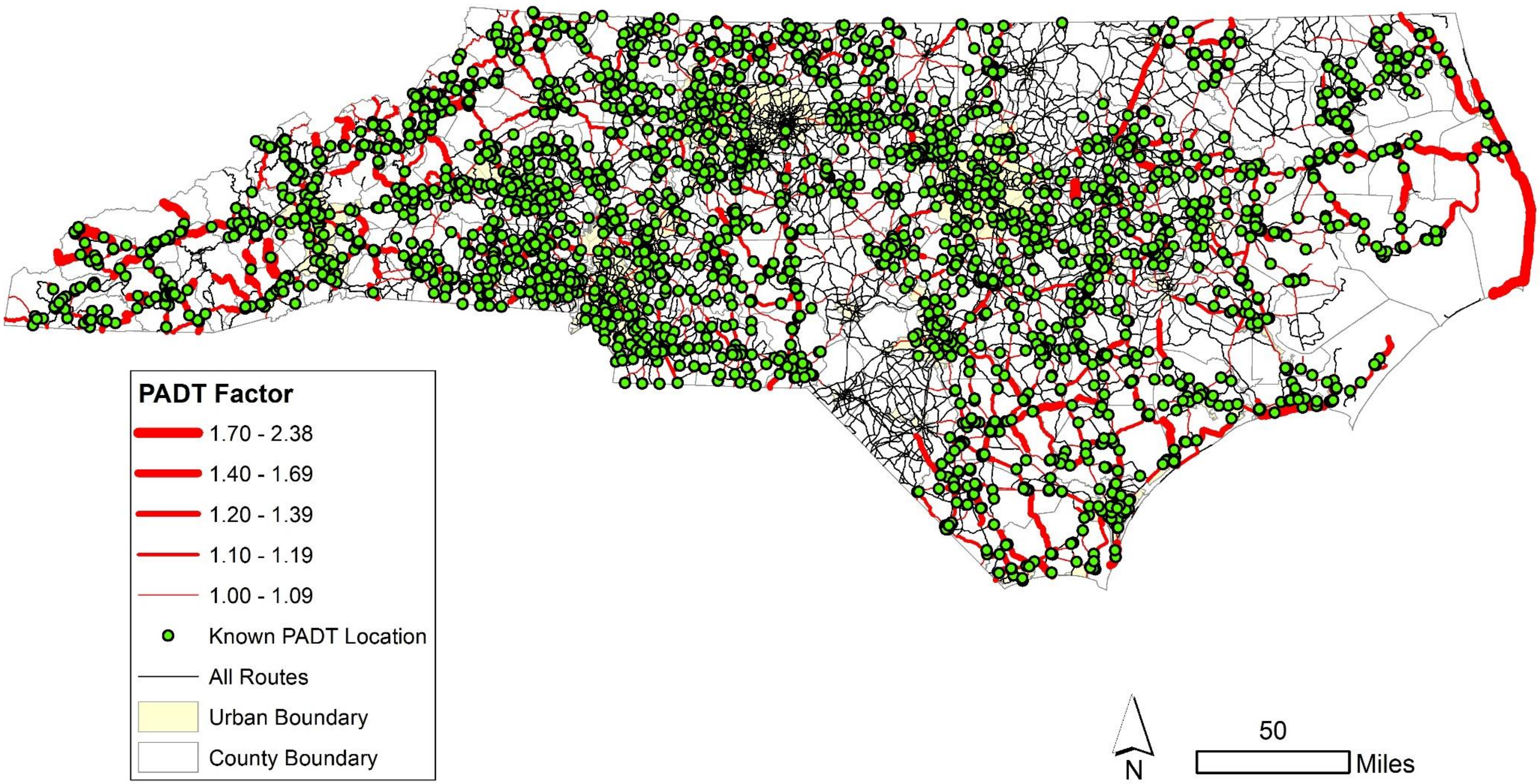


Figure 5 T3 Route Segments Excluded From PADT Factor Assignment

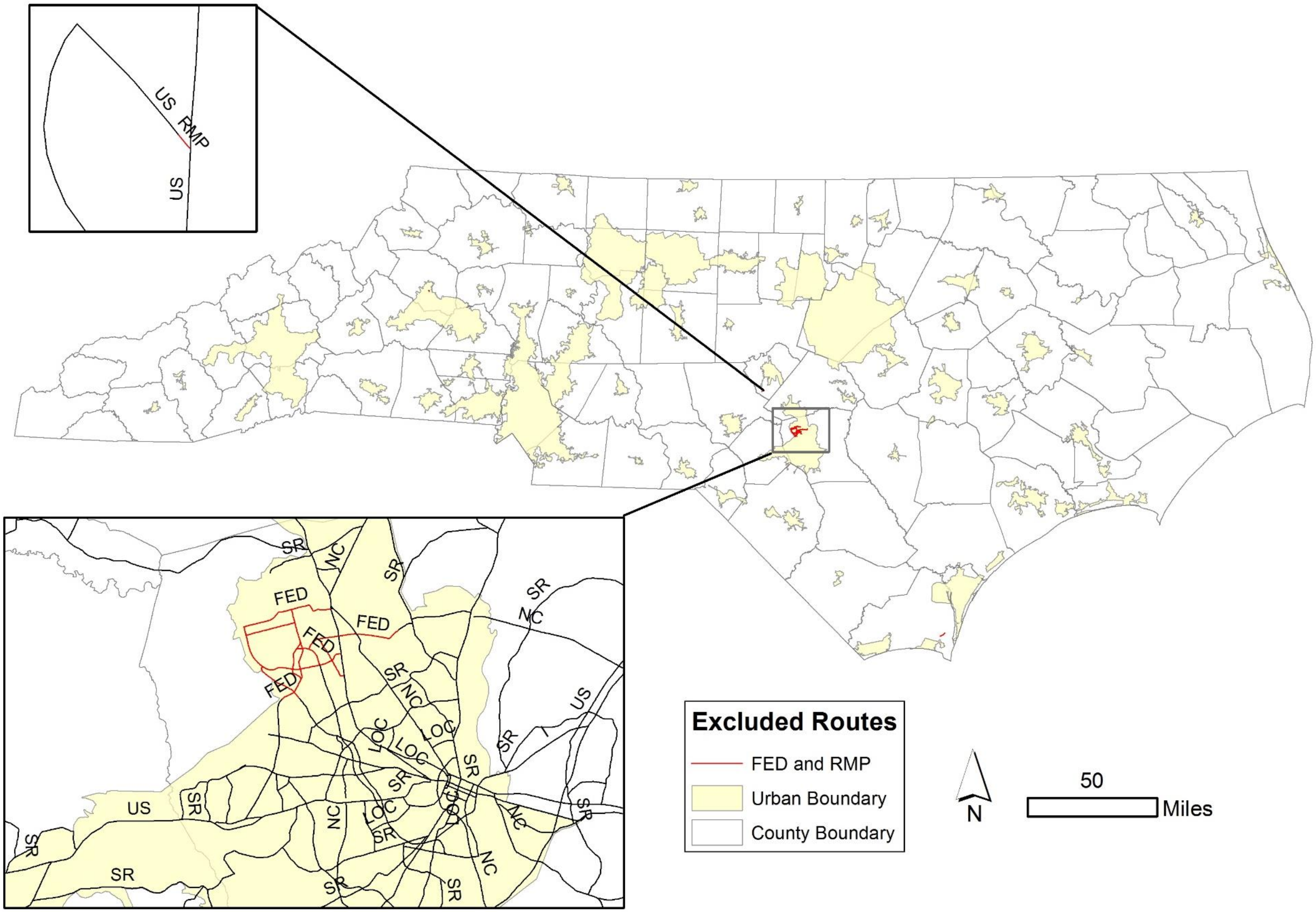
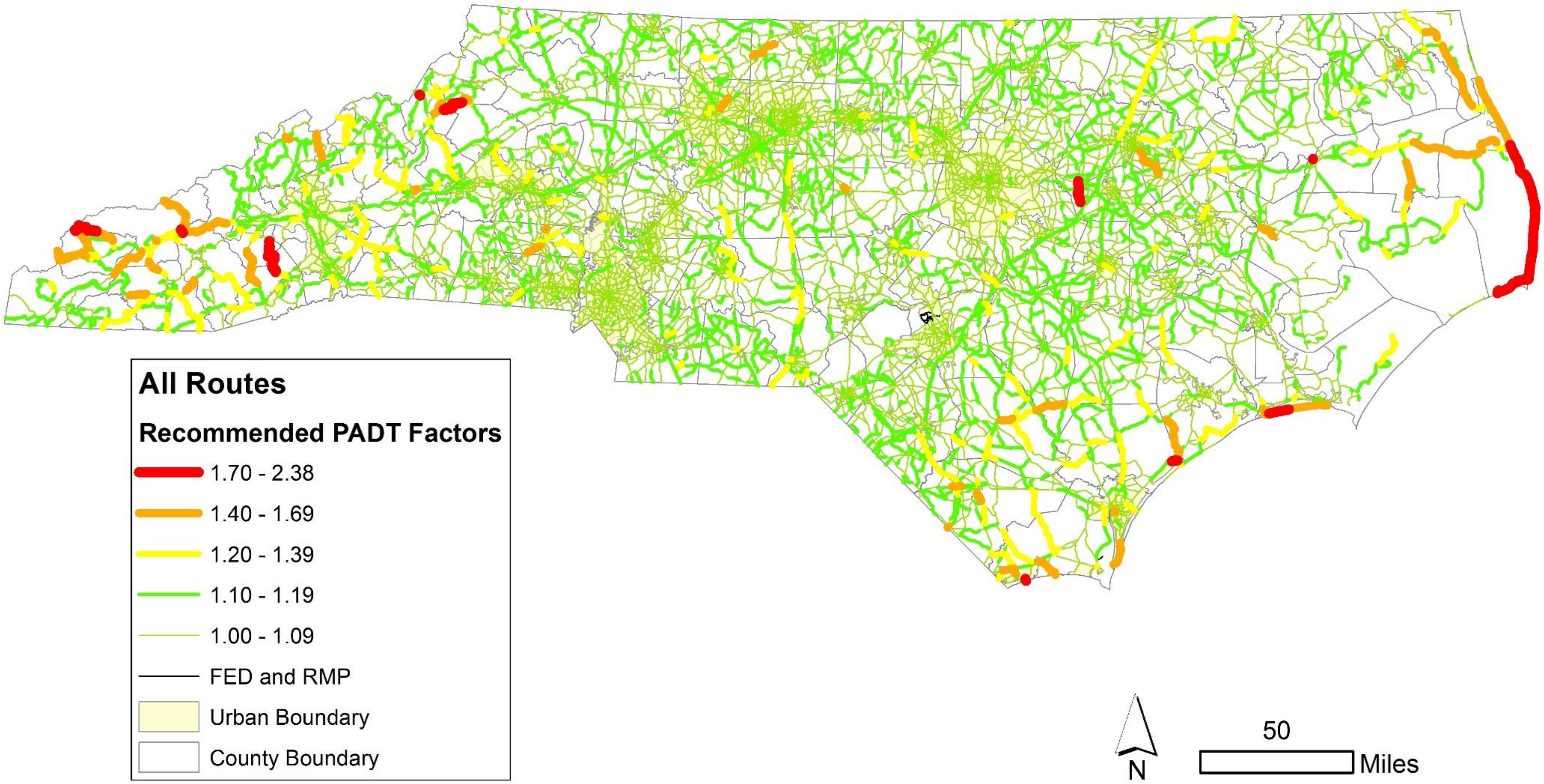


Figure 6 Recommended PADT Factors for All Routes



Data Transfer

Using the PADT estimation and extrapolation methodology developed by the research team, the NCDOT Traffic Survey Group transferred and updated the PADT data calculated by ITRE using 2013 AADTs and referencing to reflect 2014 AADTs and referencing.

In general, the data transfer process was accomplished with the following steps:

1. Transferring the known and extrapolated PADT factors from 2014 Q1 LRS references to 2015 Q1 LRS references,
2. Auditing the transferred factors for changes (route changes or bypasses that cause travel diversion),
3. Updating the default factors using 2014 inputs for segments identified as default based
4. Assigning known PADT factors to new 2014 segments (for those that were not included in the 2013 data set),
5. Extrapolating the new known PADT factors from Step 4, and
6. Assigning default factors to the remaining new segments.

Specific data transfer procedures and detailed results are included in Appendix C.

PADT RESULTS IN PRIORITIZATION

Upon completion of the data transfer process by the NCDOT Traffic Survey Group, the research team analyzed the 2014 PADT factor results in relation to roadways prioritized under the State Transportation Improvement Program (STIP). The STIP is a 10-year transportation plan that includes nearly 1,100 projects in North Carolina, and was developed using the 2013 Strategic Transportation Investments Law (STI)'s Strategic Mobility Formula. These STI roadways are classified into three categories for funding purposes: 1) Division Needs, 2) Regional Impact, and 3) Statewide Mobility. Maps were generated to visualize the 2014 PADT factor results for all STI roadways and across the three funding categories. Maps with specific details for the three funding categories are included in Appendix D.

Of particular interest to the research team was the application of the PADT factors to AADTs in order to better understand the roadway volume changes that result from seasonal traffic loads. This is important because the PADT factors on their own do not fully represent the impact to traffic volume. For example, the highest known PADT factor calculated from the seasonal coverage count data was 2.96 from a station located on SR 1409 in Edgecombe County. This factor was applied to a 2014 AADT of 220 resulting in a PADT of 660. The resulting volume change would have a minimal impact on the prioritization process. The opposite scenario can also be found. For instance, large volume changes can be seen in urban areas on roadways with low PADT factors as a result of overall higher traffic volumes.

A comparison of PADT factor results and volume change (PADT-AADT) results for all STI roadways is provided in Figures 7 and 8, respectively. It is apparent that roadways in urban areas experience the most volume change relative to PADT even when their PADT factors are low. In rural areas, there are fewer roadways with high volume changes, but these roadways appear to be key routes that enable major recreational travel. Despite having lower volumes, the magnitude of volume changes on rural recreational routes are at similar levels to the high volume change urban routes.

Figure 7 Recommended PADT Factors for All STI Routes

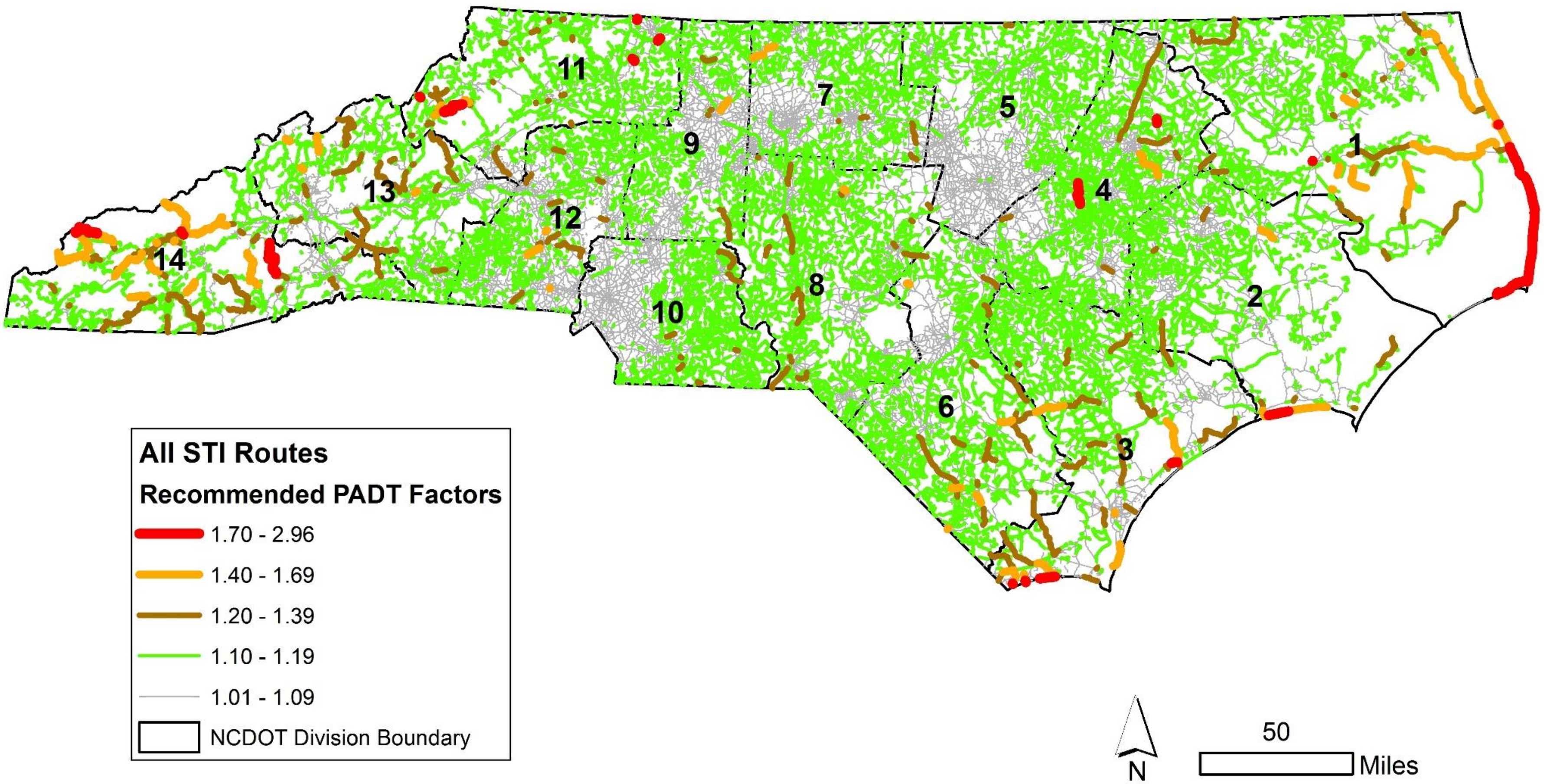
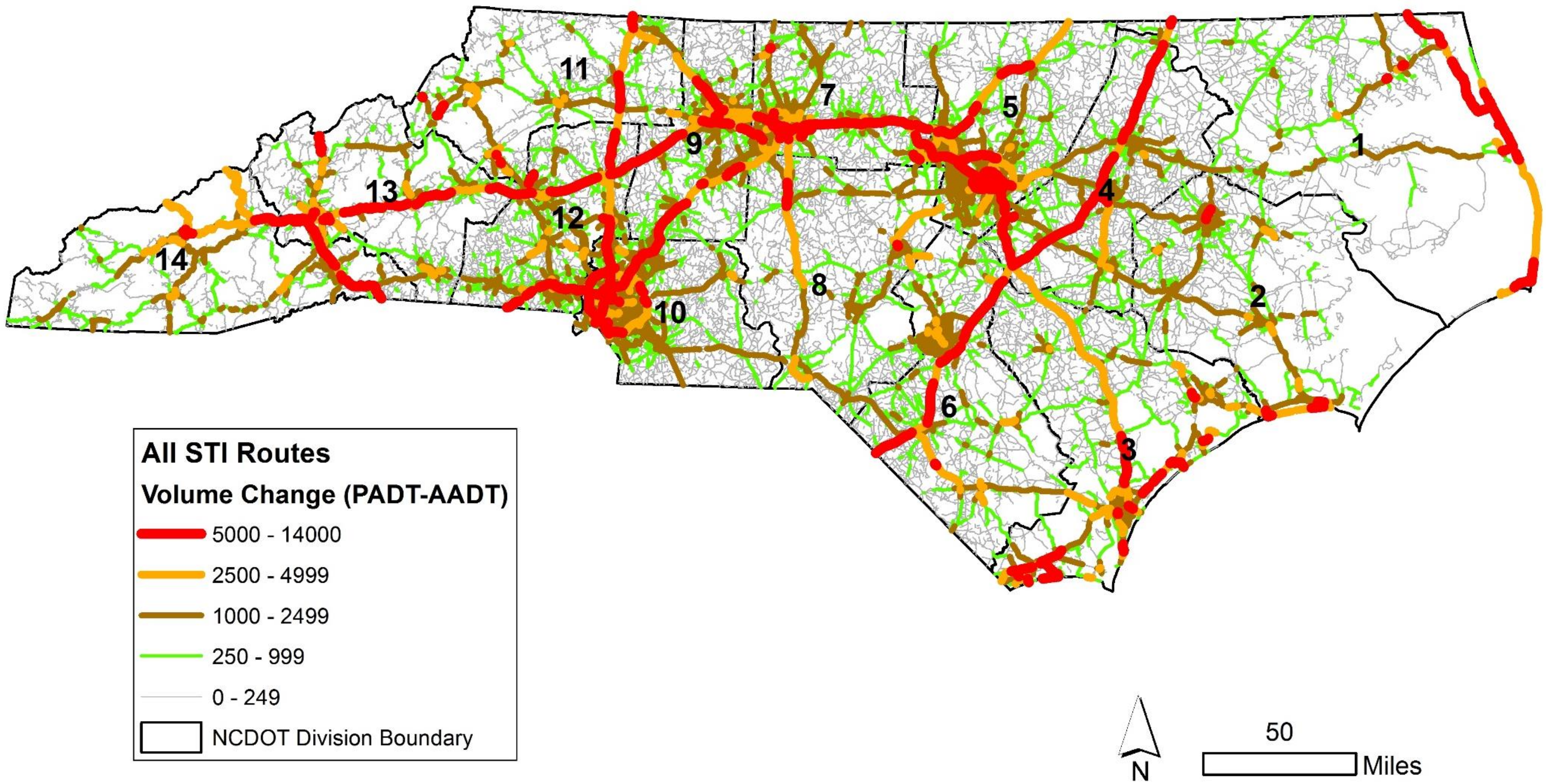


Figure 8 Volume Change (PADT-AADT) for All STI Routes



FUTURE RESEARCH

In future research, an analysis of PADT could be taken one step further by examining volume change (PADT-AADT) as a percentage of capacity. This analysis would more directly relate the impact of using PADT in the prioritization process than an analysis of volume change alone. It is expected that a map visualizing volume change as a percentage of capacity would support the claim that many roadways in urban locations with high volume changes would impact prioritization less than the rural recreational routes with high volume changes in relation to overall roadway capacity. While this analysis is outside the scope of the present research contract, it is critical for fully understanding the application of PADT in the prioritization process.

In addition, specific guidance is needed for strategically locating permanent count stations and for conducting coverage counts to allow for broader coverage of counts for future PADT factor estimation efforts. As part of this project, the research team will develop such guidance specifically for Interstates, since they showed the lowest sampling rates across route types studied in this project. However, coverage counts for all route types should be prioritized and strategically targeted to support PADT factor estimation in the future.

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APPENDIX A: PADT FACTOR CALCULATION DETAILS

A.1 Continuous Count Data

Table 12 AASHTO AADT and PADT Factor Estimation Results for Continuous Count Stations

Station ID	AADT	Fac_1	Fac_12	Fac_30	Fac_ month	Station ID	AADT	Fac_1	Fac_12	Fac_30	Fac_ month
0A0501	4,800	1.31	1.25	1.22	1.13	0A6301	22,910	1.38	1.32	1.26	1.05
0A0701	3,450	1.44	1.32	1.27	1.06	0A6302	1,350	1.41	1.28	1.23	1.09
0A0901	3,070	1.66	1.38	1.28	1.14	0A6303	40,230	1.96	1.85	1.68	1.22
0A1001	54,840	1.24	1.21	1.20	1.06	0A6401	13,200	1.21	1.19	1.17	1.04
0A1003	49,710	1.43	1.37	1.31	1.15	0A6403	26,600	1.79	1.63	1.53	1.37
0A1101	42,560	1.40	1.32	1.27	1.09	0A6405	45,640	1.25	1.23	1.20	1.05
0A1302	8,180	2.05	1.63	1.50	1.27	0A6701	980	1.52	1.47	1.41	1.29
0A1501	18,430	2.26	1.94	1.77	1.57	0A7101	14,730	1.34	1.26	1.23	1.05
0A1801	15,540	1.35	1.29	1.25	1.06	0A7301	16,850	1.41	1.31	1.28	1.12
0A2501	50,720	1.29	1.25	1.22	1.04	0A7302	16,720	1.39	1.33	1.29	1.11
0A2502	47,830	1.69	1.55	1.45	1.13	0A8101	4,180	1.36	1.30	1.27	1.04
0A2503	3,810	1.23	1.20	1.16	1.05	0A8401	3,300	1.35	1.28	1.24	1.05
0A2701	4,500	3.31	2.86	2.36	1.84	0A8502	5,000	1.32	1.24	1.20	1.06
0A2702	3,680	3.35	2.77	2.26	1.56	0A8602	4,320	1.80	1.67	1.59	1.41
0A2703	18,930	2.54	2.38	2.04	1.50	0A8901	540	1.42	1.27	1.22	1.06
0A3001	1,650	1.32	1.25	1.22	1.07	0A9001	450	1.34	1.28	1.24	1.12
0A3002	7,280	1.35	1.27	1.23	1.06	0A9101	26,990	1.31	1.24	1.21	1.04
0A3003	8,190	1.63	1.42	1.33	1.12	0A9104	28,970	1.30	1.25	1.23	1.10
0A3103	14,750	1.26	1.24	1.23	1.04	0A9105	1,390	2.27	1.65	1.46	1.32
0A3104	62,780	1.31	1.26	1.25	1.06	0A9106	5,310	1.41	1.28	1.23	1.05
0A3201	720	1.47	1.33	1.27	1.13	0A9107	66,940	1.36	1.28	1.25	1.09
0A3303	11,230	1.32	1.23	1.20	1.03	0A9108	111,090	1.27	1.22	1.20	1.06
0A3501	2,470	1.33	1.24	1.20	1.10	0A9501	3,470	1.42	1.32	1.27	1.05
0A3502	1,020	1.63	1.46	1.44	1.08	0A9601	9,210	2.14	1.68	1.54	1.24
0A4005	1,010	1.41	1.37	1.35	1.10	0W1401	12,010	1.29	1.25	1.22	1.05
0A4008	26,890	1.30	1.24	1.22	1.03	0W1701	26,260	1.29	1.25	1.22	1.06
0A4012	48,430	1.31	1.27	1.24	1.06	0W1803	9,780	1.45	1.33	1.27	1.04
0A4013	56,310	1.44	1.32	1.28	1.06	0W1805	10,520	1.39	1.35	1.28	1.07
0A4201	14,370	1.35	1.28	1.26	1.08	0W2301	12,770	1.76	1.54	1.44	1.21
0A4301	5,980	1.44	1.28	1.23	1.11	0W2802	19,210	1.24	1.21	1.19	1.05
0A5001	41,780	1.52	1.40	1.34	1.13	0W4701	1,740	1.46	1.36	1.29	1.12
0A5301	3,880	1.40	1.26	1.20	1.11	0W7001	22,570	2.00	1.76	1.59	1.26
0A5903	74,020	1.26	1.18	1.16	1.03	0W7002	3,760	1.36	1.24	1.20	1.06
0A5905	5,570	1.63	1.57	1.48	1.30	0W7501	17,400	2.02	1.82	1.57	1.25
0A5907	28,880	1.22	1.18	1.16	1.04	0W8501	25,770	1.82	1.59	1.47	1.17
0A6201	1,400	1.40	1.30	1.26	1.09	-	-	-	-	-	-

Table 13 Monthly Analysis Results for ‘Fac_month’ PADT Factors >1.2 for Continuous Count Stations

Station ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Fac_Month	County	Route
A2701	0.42	0.41	0.56	0.83	1.22	1.62	1.84	1.71	1.35	0.95	0.64	0.45	1.84	DARE	NC 12
A1501	0.68	0.70	0.84	0.96	1.21	1.40	1.57	1.30	1.02	0.91	0.76	0.66	1.57	CARTERET	SR 1182
A2702	0.58	0.60	0.75	0.89	1.15	1.44	1.56	1.35	1.19	1.02	0.82	0.67	1.56	DARE	US 64
A2703	0.65	0.67	0.80	0.98	1.13	1.35	1.50	1.46	1.13	0.88	0.77	0.68	1.50	DARE	US 158
A8602	0.63	0.68	0.79	0.95	1.09	1.29	1.41	1.26	1.18	1.14	0.84	0.73	1.41	SWAIN	US 19
A6403	0.77	0.77	0.88	1.02	1.19	1.24	1.37	1.24	1.08	0.91	0.80	0.74	1.37	NEW HANOVER	US 74-76
A9105	0.89	0.97	0.96	0.99	0.99	0.98	0.93	0.97	0.93	0.96	1.12	1.32	1.32	WAKE	SR 1669
A5905	0.89	0.94	0.99	1.00	0.99	0.98	1.02	0.99	1.30	1.00	0.92	0.97	1.30	MECKLENBURG	CINDY LANE
A6701	0.84	0.89	0.94	1.10	1.29	1.21	0.92	0.95	1.00	1.01	0.94	0.92	1.29	ORANGE	SR 1102
A1302	0.83	0.84	0.82	0.92	1.00	1.06	1.11	1.13	1.11	1.27	1.00	0.91	1.27	CALDWELL	US 321
W7001	0.77	0.82	0.96	1.01	1.11	1.16	1.26	1.19	0.97	0.92	0.93	0.90	1.26	PENDER	I-40
W7501	0.74	0.81	0.95	1.00	1.05	1.19	1.25	1.17	1.05	1.00	0.91	0.88	1.25	RANDOLPH	I-73-74/US 220
A9601	0.81	0.85	0.87	0.95	1.00	1.01	1.09	1.14	1.10	1.24	1.02	0.93	1.24	WILKES	US 421
A6303	0.81	0.82	1.04	1.01	0.99	1.07	1.21	1.22	0.89	0.91	0.95	1.08	1.22	NASH	I-95
W2301	0.76	0.88	0.92	1.06	1.11	1.17	1.21	1.08	0.99	0.98	0.94	0.91	1.21	COLUMBUS	US 74-76

Table 14 ANOVA Test Results for PADT Factors by Route Type for Continuous Count Stations

ANOVA Table						
Source	SS	df	MS	*F*	$F_{critical}$	*p*-value
Between	0.2906	3	0.0969	0.5214	2.7505	0.6691
Within	11.7054	63	0.1858			
Total	11.9961	66				
Confidence Intervals for Group Means						
Group	Confidence Interval			1–α		
Interstate	1.5653	±	0.2389	95%		
US	1.5667	±	0.1658	95%		
NC	1.6861	±	0.3256	95%		
SR	1.4632	±	0.1926	95%		

Confidence Intervals for Group Means – Plot

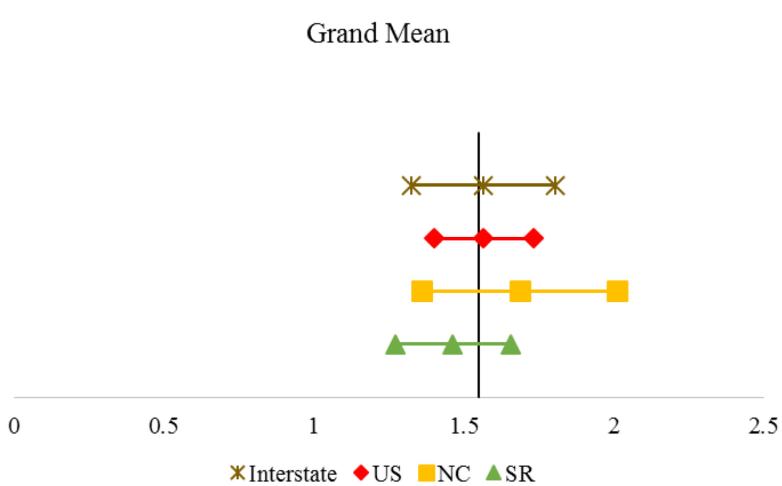
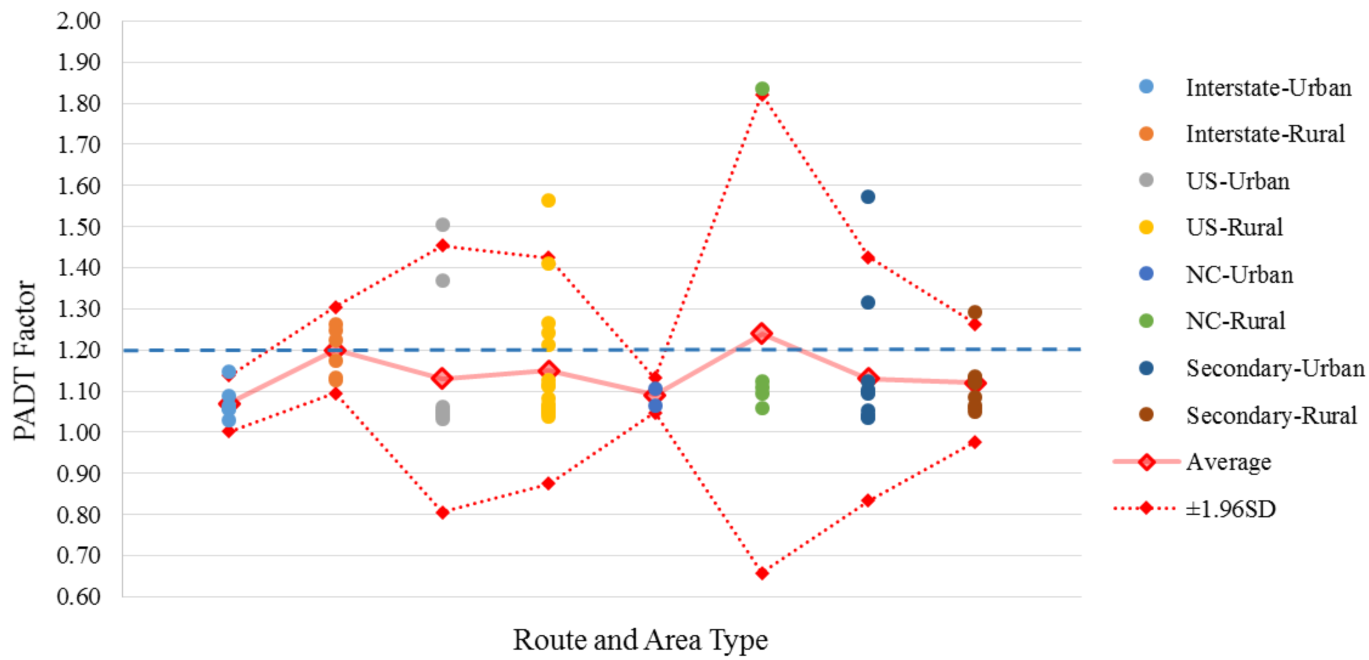


Table 15 Two Sample *t*-test Results for PADT Factors by Area Type for Continuous Count Stations

Route Type	Urban	Rural
Mean	1.4393	1.6361
Variance	0.1093	0.2274
Observations	30	37
Pooled Variance	0.1747	
df	65	
t Stat	-1.9159	
P(T≤t) one-tail	0.0299	
t Critical one-tail	1.6686	
P(T≤t) two-tail	0.0598	
t Critical two-tail	1.9971	

Figure 9 PADT Factor Analysis Results Diagram by Route and Area Type for Continuous Count Stations



A.2 Seasonal Coverage Count Data

Table 16 Example Seasonal Coverage Count Data for Two Count Locations

ID	Month	Day	Date	SUN	MON	TUE	WED	THU	FRI	SAT	Counts	Route	Location
5503400	1	3	16-Jan-07	361	615	553	446	n/a	571	465	6	SR 1625	S OF NC 106
	5	2	07-May-07	444	807	747	694	803	643	672	7	SR 1625	S OF NC 106
	7	2	09-Jul-07	432	731	733	585	828	667	694	7	SR 1625	S OF NC 106
	11	4	14-Nov-07	437	n/a	n/a	643	679	605	583	5	SR 1625	S OF NC 106
5600001	2	4	14-Feb-01	1653	1531	n/a	1558	1523	1640	1717	6	US 25-70	E OF SR 1183
	4	4	04-Apr-01	n/a	n/a	n/a	1686	1659	2106	2267	4	US 25-70	E OF SR 1183
	6	4	06-Jun-01	2355	1790	n/a	1800	1918	2089	2406	6	US 25-70	E OF SR 1183
	7	3	10-Jul-01	1681	n/a	1722	1923	2010	2414	2250	6	US 25-70	E OF SR 1183
	10	5	04-Oct-01	2112	1684	n/a	n/a	2005	2078	1865	5	US 25-70	E OF SR 1183

** n/a: no data available*

Table 17 Number of Locations for Counted Weeks

Counted weeks	Number of Locations	Percentage
10	13	0.4%
9	3	0.1%
8	0	0.0%
7	0	0.0%
6	28	0.8%
5	2,944	80.1%
4	355	9.7%
3	76	2.1%
2	53	1.4%
1	204	5.5%
Total	3,676	100.0%

Table 18 Number of Counted Weeks for Each Day

Day	Counted Days	Missing Days	Percentage of Missing Days
SUN	15,849	1,154	6.8%
MON	12,488	4,515	26.6%
TUE	11,897	5,106	30.0%
WED	13,899	3,104	18.3%
THU	15,612	1,391	8.2%
FRI	16,625	378	2.2%
SAT	16,340	663	3.9%
Total weeks	17,003	-	-

PADT Factor Estimation Method Comparison for Seasonal Coverage Data

The research team developed two slightly different methods, SPEC and MAX, based on different threshold levels for treating missing data. The SPEC method applied a more stringent filtering criterion to arrive at a more conservative dataset, while the MAX method was used to maximize the number of locations available for data analysis (yet still filtering those locations with incomplete data). As a result, the SPEC method resulted in a total of 2,658 valid locations while the MAX method had 3,204 locations. A detailed description of how each method was defined is presented in the following subsections.

SPEC Method

The SPEC method was originally proposed by NCDOT for identifying and using locations that had consistent and complete traffic volume data. There are three weekly data conditions for locations to be selected in the SPEC method as follows:

- Friday, Saturday, and Sunday must have traffic data.
- There must be at least two days of data among Monday, Tuesday, Wednesday, and Thursday.
- There must be at least four weeks of data available for the location after applying the first two conditions.

Once the SPEC method locations were selected, the next step was to handle any weekdays (Monday through Thursday) that were missing data. Any missing data were substituted by the average of the rest of available weekday data. The team identified a total of 2,658 valid locations in the SPEC method.

MAX Method

The MAX method was developed by the team to maximize the number of reliable location data, by relaxing some of the criteria in the SPEC method. The result is a larger sample than SPEC, while encompassing all the prior SPEC locations. There are three conditions for locations to be selected in the MAX method as follows:

- Either Saturday or Sunday must have valid traffic data.
- There must be at least one day of data among Monday, Tuesday, Wednesday, and Thursday (although 96.5% of weeks had two or more days available as discussed below).
- There must be at least four weeks of data available for the location after applying the first two conditions (same as SPEC method).

Before the research team accounted for missing data, the team had to evaluate the relationship between Friday traffic data and other days. The level of Friday traffic could be very different compared to weekdays or weekends depending on a certain area or route. Therefore, the team conducted a statistical (linear comparison) test between Friday and the rest of the weekday data and between Friday and weekend data. In the first test (between Friday and the rest of the weekday traffic data), the team found that 34% of locations had a significant difference at the 95th percentile confidence level. In the second test (between Friday and weekend traffic data), the team identified that 69% of locations had a significant difference at the same confidence level. Therefore, the level of Friday traffic data was much closer to weekday than weekend conditions.

Considering the Friday data evaluation results, the team handled missing data in the MAX method as follows:

- Saturday missing data were substituted by Sunday data and vice versa.
- Any missing data on Monday, Tuesday, Wednesday, or Thursday were substituted by the average of the rest of available weekday (Monday through Thursday) data.
- Friday missing data were substituted by the average of the available weekday (Monday through Thursday) data.

After applying these filters, the team identified a total of 3,204 valid locations in the MAX method (a 20% increase over the SPEC method).

Table 19 MAX Method Week Data Distribution

Number of weekdays	Fr, Sa, Su	Fr, Sa	Fr, Su	Sa, Su	Sa only	Su only	Total
4	6385 (41.5%)	208 (1.4%)	7 (0.0%)	4 (0.0%)	0 (0.0%)	1 (0.0%)	6605 (43.0%)
3	5602 (36.4%)	142 (0.9%)	3 (0.0%)	3 (0.0%)	1 (0.0%)	4 (0.0%)	5755 (37.4%)
2*	2395 (15.6%)	72 (0.5%)	6 (0.0%)	10 (0.1%)	2 (0.0%)	2 (0.0%)	2487 (16.2%)
1	505 (3.3%)	22 (0.1%)	1 (0.0%)	1 (0.0%)	2 (0.0%)	0 (0.0%)	531 (3.5%)
Total	14887 (96.8%)	444 (2.9%)	17 (0.1%)	18 (0.1%)	5 (0.0%)	7 (0.0%)	15378 (100.0%)

* SPEC Method minimum threshold

Table 20 PADT Factor Distribution

PADT factor	SPEC		MAX		Additional MAX data	
	# of Locations	Percentage	# of Locations	Percentage	# of Location	Percentage
< 1.1	1,899	71%	2,271	71%	374	68%
1.1 to 1.2	527	20%	627	20%	104	19%
1.2 to 1.3	126	5%	158	5%	29	5%
1.3 to 1.4	53	2%	68	2%	16	3%
> 1.5	53	2%	80	2%	23	4%
Total	2,658	100%	3,204	100%	546	100%

Figure 10 PADT Factor Distribution Comparison

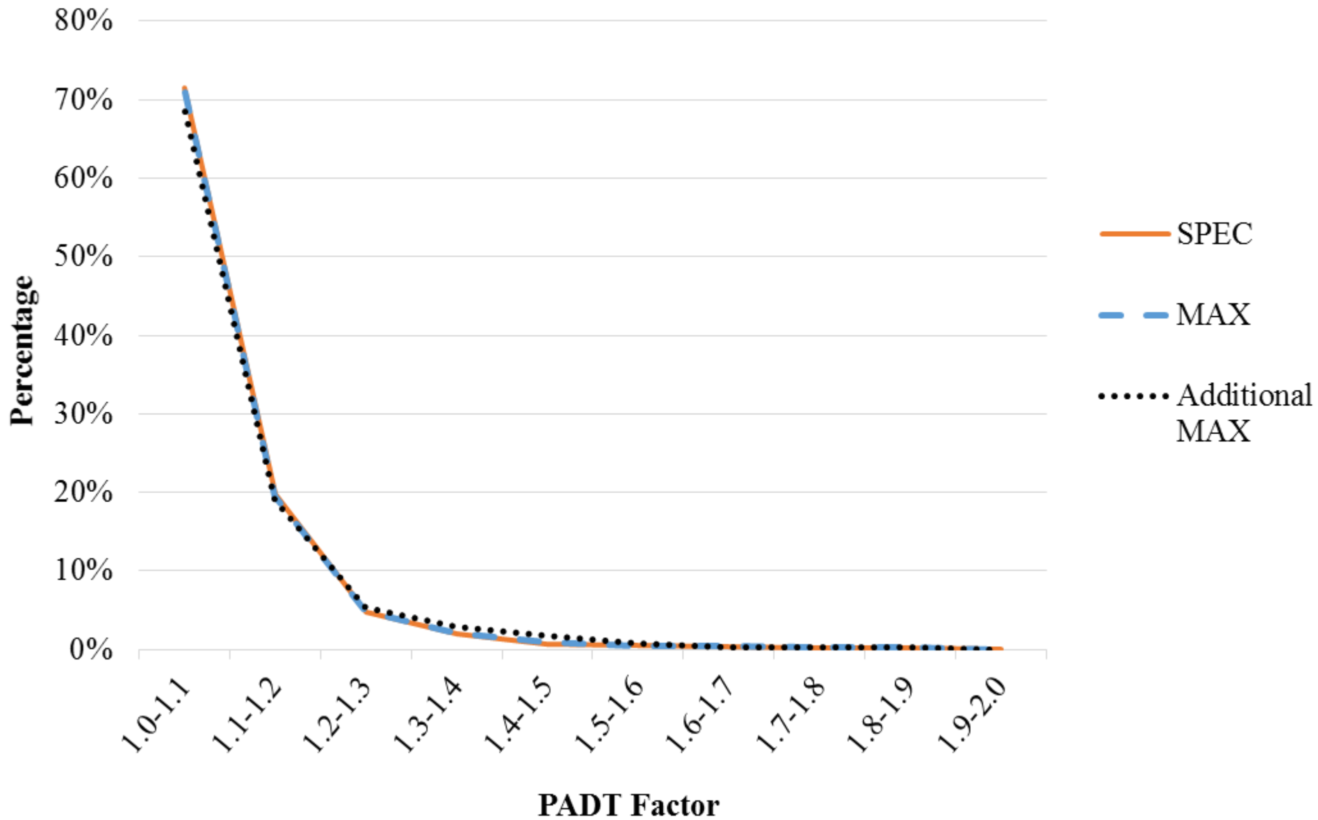


Figure 11 MAX vs. SPEC Location Comparison

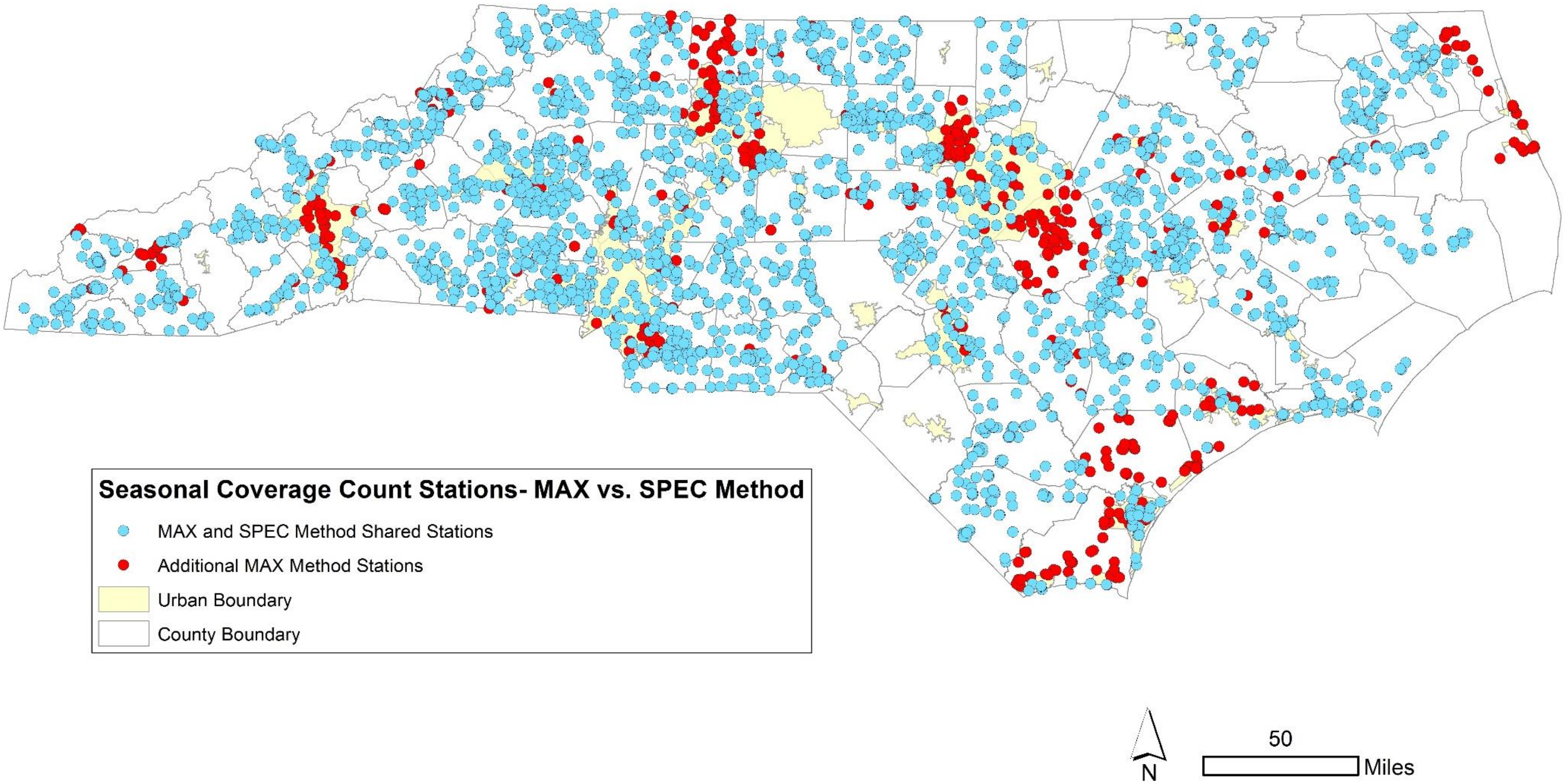
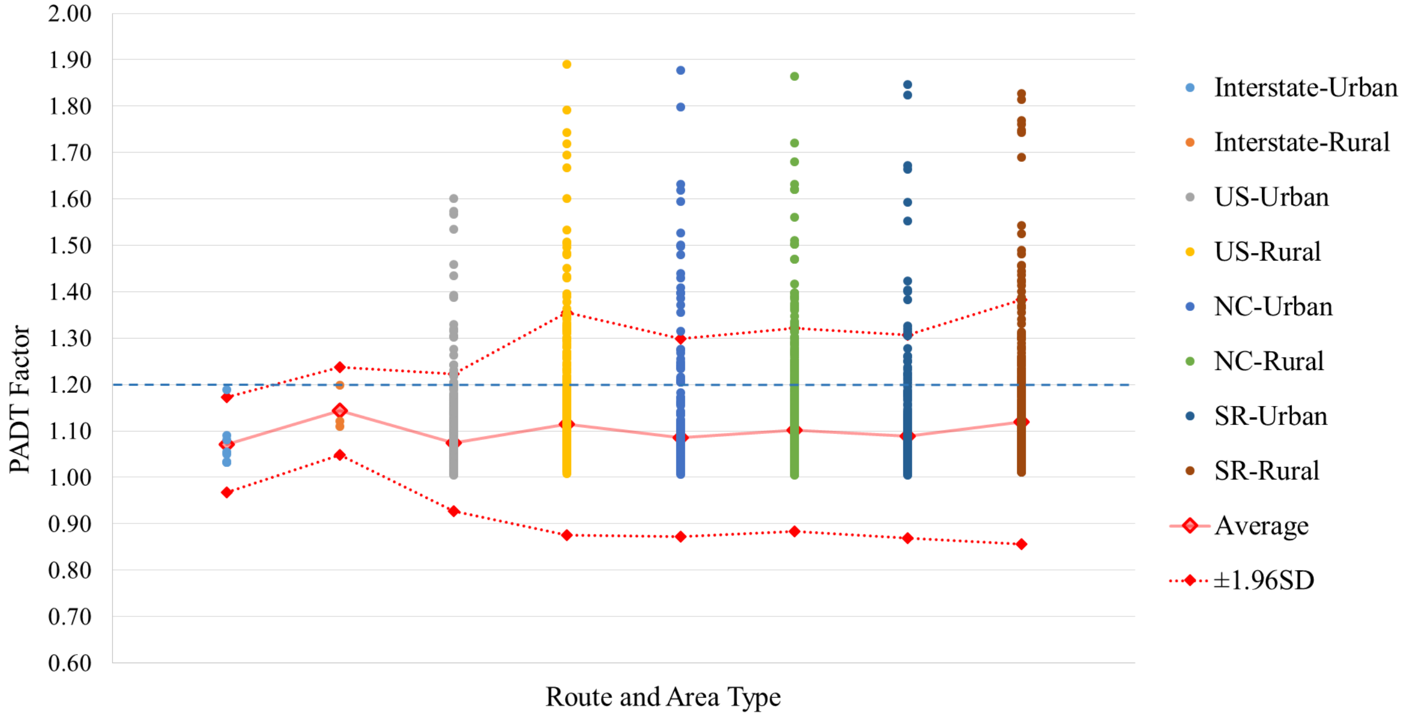


Figure 12 PADT Factor Analysis Results Diagram by Route and Area Type for Seasonal Coverage Count Stations



APPENDIX B: DATA EXTRAPOLATION DETAILS

SEG_T3 and STA_T3 GIS files were attributed with route type and urban/rural area type from NCDOT's 2015 Q1 Road Characteristics shape file using spatial joins. The resulting attribute table was exported and used as the basis for data preparation and storage. Data preparation was primarily performed in Excel. Urban/rural area type was recoded from URBN_ID_CD, where no data indicates that a segment is rural and any value other than 0 or null indicates that a segment is urban, into a binary where Urban = 1 and Rural = 0. Table contains the final data table field names and their descriptions.

Table 21 Final Data Table Field Names and Descriptions

Field Name	Description
CVRG_VLM_I	A unique identifier assigned to each traffic monitoring station location by the NCDOT.
AADT2013	The 2013 AADT for the segment.
RTE_1_CLASS	The NCDOT route class code for the dominant route for the segment.
RTE_1_NBR	The NCDOT route number for the dominant route for the segment.
STREET_NAM	The NCDOT name of the dominant route for the segment.
RTE_NM	The NCDOT concatenation of Route Class, Route Number and Route Qualifier that also contains important co-routes.
URBAN	Urban (1) or Rural (0) setting.
PADT_D	The default PADT factor for the segment.
PADT_ND	The non-default (MAX method) PADT factor for the segment, when applicable. 99 indicates that no MAX method PADT factor can be applied.
PADT_EX	The extrapolated PADT factor for the segment, when applicable. 99 indicates that no extrapolated PADT factor can be applied.
PADT_REC	The recommended PADT factor for the segment.

All fields except PADT_EX, PADT_REC, and REC_TYPE were filled with available data. For field PADT_ND, "99"s were used where values were not known. The updated data table was joined to the original T3 point and line segment GIS files. Two new shapefiles were then exported: 1) A line shape file with segments with known PADT values (PADT_ND does not equal "99"), and 2) a line segment shape file with station locations to be extrapolated to (PADT_ND = "99").

Preliminary data extrapolation was performed using the following steps:

1. Split the two new shapefiles by attribute using USGS's "Split by Attribute Tool" (http://www.umesc.usgs.gov/management/dss/split_by_attribute_tool.html)
    a. Line segment shapefile
        - Feature Layer: Line segments with known PADT values (PADT_ND does not equal 99)
        - Split Field = Rte_Nm
    b. Point shapefile
        - Feature Layer: Line segments to be extrapolated to (PADT_ND = 99)
        - Split Field = Rte_Nm

2. Iterate spatial join between resulting layers using a Batch Spatial Join
    - Target = Line layers to be extrapolated to
    - Join = Line layers with known PADT values
    - One-to-One
    - Closest

3. Merge the individual spatially joined layers into one layer that contains all the preliminary extrapolated data results

4. QA/QC the new merged layer using an Urban Check and manual editing in Excel
    a. Export the attribute table from the new merged layer as a .dbf file and open in Excel
    b. Remove unnecessary fields, reformat headings as needed
    c. Include additional sheets named “Segments to Extrapolate to,” “ND [Known PADT] Segments,” “Extrapolated and Default Only [Segments],” “Urban Check,” “Urban Check Remove,” and “Extrapolation Manual Edit”
    d. In “Segments to Extrapolate to” sheet, include a column with a VLOOKUP formula that calls out which segments were assigned a known PADT value through the preliminary extrapolation and which segments are default-only
    e. In the “Extrapolated and Default Only” sheet, combine all the data from the first sheet and the default-only data from the “Segments to Extrapolate to” sheet
    f. In the “ND Segments” sheet, add the data for segments with known PADT values (PADT_ND does not equal 99)
    g. In “Urban Check” sheet, include a column with an IF formula that calls out where Urban/Rural setting is the same or different for matched segments. Include an additional column that indicates whether a segment was extrapolated to or not (Y or N). If Urban/Rural setting is different for matched segments, the entry in the extrapolation column should be no (N).
    h. In the “Urban Check Remove” sheet, where Urban/Rural setting is different for matched segments, remove the information for the segments with known PADT values
    i. In the “Extrapolation Manual Edit” sheet, copy over the data from the “Urban Check Remove” sheet and simplify the table. Add a column for known PADT values for the segments that were extrapolated from that uses a VLOOKUP formula to reference the “ND Segments” sheet

5. Continue manual editing by joining the “Extrapolation Manual Edit” sheet to the T3_SEG shape file in ArcGIS and visually inspecting and correcting the extrapolation results based on the conditions detailed below.

Manual Editing of Preliminary Extrapolation Results

To summarize, in order to produce the preliminary extrapolation results, the known PADT factor for a continuous or coverage count station was assigned to the nearest traffic monitoring station segment in SEG_T3, and the known PADT factors were then applied to adjacent route segments in both directions using a spatial join. The results were then manually edited to limit extrapolation based on the following conditions for the listed route classes:

Interstate Routes

1. an intersection with another Interstate route,
2. an intersection with a US route, or
3. an urban/rural boundary.

US Routes

1. an intersection with an Interstate route,
2. an intersection with another US route, or
3. an urban/rural boundary

NC Routes

1. an intersection with an Interstate route,
2. an intersection with a US route,
3. an intersection with another NC route, or
4. an urban/rural boundary.

For US and NC routes, extrapolation was also limited at locations where the dominant flow of traffic appeared to be interrupted by a signalized or stop sign controlled intersection with any route type. No extrapolation was performed for SR routes beyond assigning known PADT factors to their respective stations in the T3 dataset.

Exceptions to Extrapolation Rules

The following issues/exceptions should be noted when performing the extrapolation:

1. Urban/rural point vs. segment location
2. Closest point vs. closest segment
3. Change in route designation along continuous roadway
4. Change in AADT along route
5. Segment crosses major route condition

APPENDIX C: DATA TRANSFER DETAILS

The PADT factor calculation methodology was developed by the ITRE research team with the assistance of NCDOT. The methodology was developed by evaluating available continuous and seasonal coverage count data. NCDOT Traffic Survey Group's data transfer procedure for 2014 data builds on the methodology developed and applied using 2013 data.

The specific methodology included the following steps:

1. Capture 2014 attributes on 2014 station points. These are:
    a. Route Type
        - PADT is assigned to Interstate, US, NC, SR, and LOC routes with a FC higher than Local (exclude Codes 7 and 8)
        - A spatial join between the PTC stations already attributed with FC and urban code (done for HPMS) was made with LRS_Arcs to capture route type (see Stations.shp)

    b. Area Type
        - Updated 2014 urban boundaries were used to determine if a station was located in an urban or rural area type

    c. 2014 AADT
        - Captured from AADT production table

2. Audit CVRG_VLM_ID that require 2014 PADT for the following:
    - Build PADT table using station list for 2014 maintenance table references
    - Identify CVRG_VLM_ID in segments that are needed for PADT that do not have station points (primarily calculated stations)
    - Attribute these missing CVRG_VLM_ID manually using the segments
    - Check CVRG_VLM_ID segments with multiple Route Types
    - Manually identify I-95 Business and I-85 Business stations that are on partial control of access facilities and attribute as US routes
    - Check stations that have CVRG_VLM_ID that are needed for PADT that had a large offset in the LRS_Arcs join

3. Transfer data from the 2013 PADT GIS file and data table prepared by ITRE to the 2014 data table
4. Attribute all 2014 stations with default PADT factors using 2014 attributes
5. Capture 2013 non-default PADT factors in 2014 REC fields
6. Capture sample (known) PADT factors not captured in 2013 and extrapolate
7. Capture recommended PADT factors from 2014 sample (known), extrapolated, or default PADT factors <u>that do not have</u> a 2013 sample (known) or extrapolated estimate
8. Calculate factored PADT by applying PADT factor to factored AADT and round for PADT estimate
9. Capture PADT estimate in 2014SEGS shapefile

APPENDIX D: STI ROADWAY MAPS BY FUNDING CATEGORY

Figure 13 Recommended PADT Factors for STI Division Needs Routes

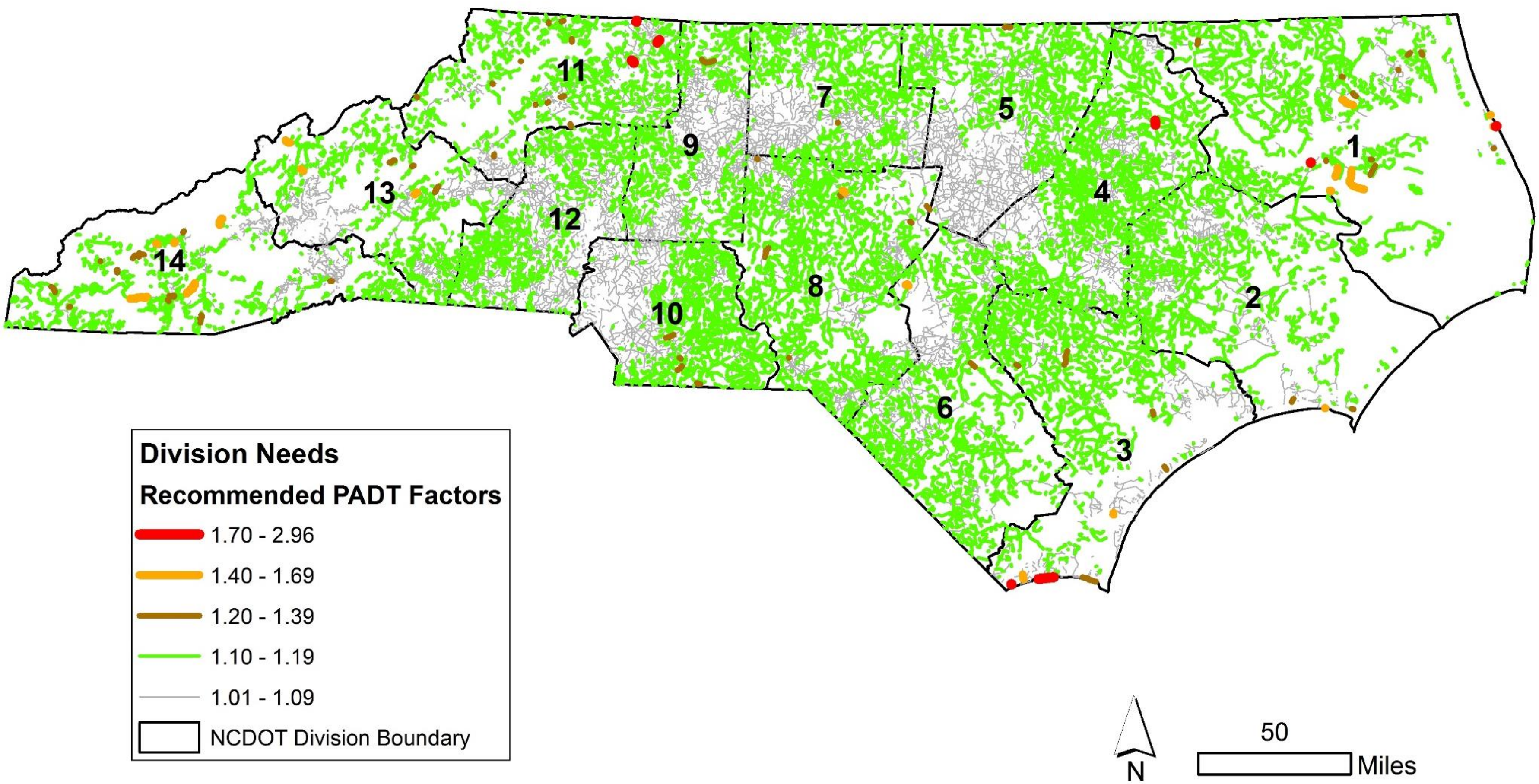


Figure 14 Recommended PADT Factors for STI Regional Impact Routes

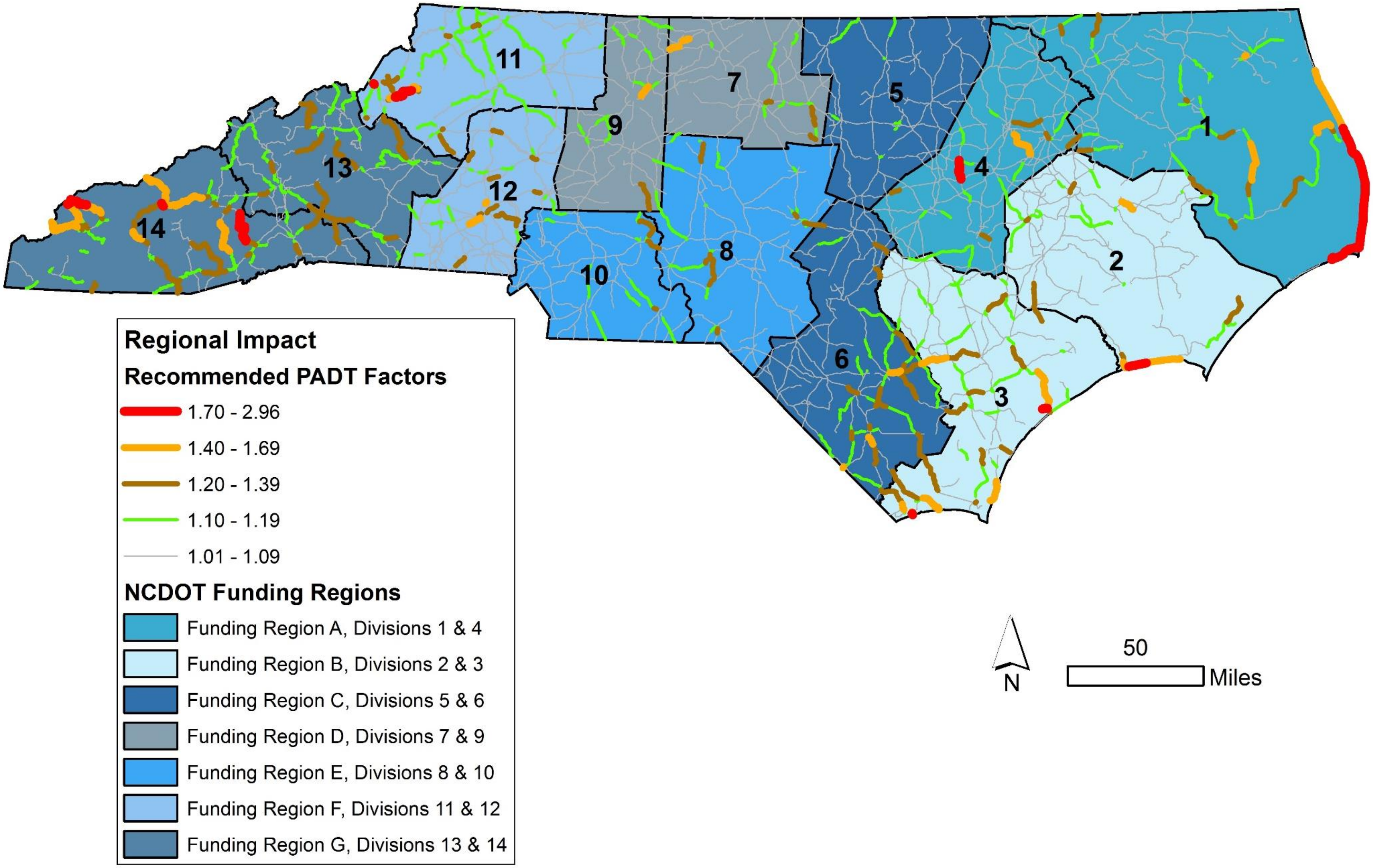
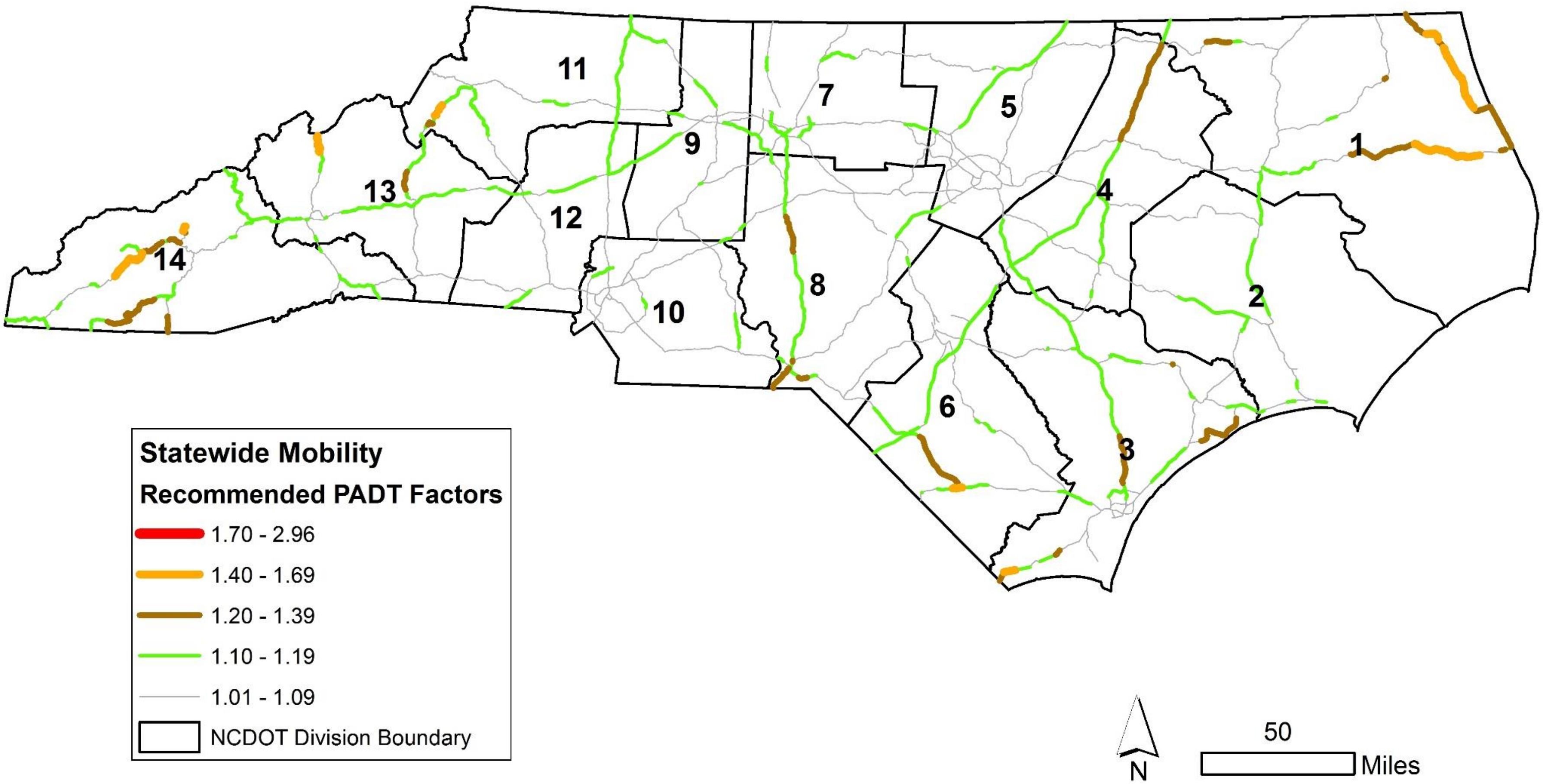


Figure 15 Recommended PADT Factors for STI Statewide Mobility Routes



Volume 2: Summary of Peak Average Daily Traffic (PADT) Factor Work for P5.0

INTRODUCTION

Volume 1 of this report summarized work by the ITRE research team that resulted in the development of Peak Average Daily Traffic (PADT) factors, the development of default PADT factors, and the extrapolation of known and default PADT factors across the North Carolina roadway network. The goal was to develop PADT factors suitable to supplement the conventional AADT in NCDOT's P4.0 prioritization process for state-maintained highways (primary and secondary routes) in 2015, and to further expand the count coverage and application of PADT for P5.0 by 2017.

Volume 2 of this report presents a plan for enhancing coverage counts and analytics for prioritization P5.0 and beyond. The primary components of this effort include 1) an evaluation of HERE.com sensor data for use in producing PADT factors for I-540 in the Triangle region, 2) calculation of PADT factors for interstates from HERE.com, sample, and continuous counts, 3) an update of interstate default PADT factors, 4) application of the interstate sampling plan to generate system-wide PADT factors using interpolation and extrapolation, and 5) a sampling plan for North Carolina counties with limited or no data for generating PADT factors to be implemented in 2017.

Both statistical and geographic information system (GIS) analyses were conducted to calculate, apply, and interpolate/extrapolate known and default PADT factors generated from HERE.com, sample, and continuous counts provided by the North Carolina Department of Transportation (NCDOT).

P5.0 PRIORITIZATION METHODOLOGY

PADT Factor Data Collection Specification

The Peak Average Daily Traffic (PADT) is an estimate of average daily traffic for the peak month of travel at a location. The PADT factor is used to generate an estimate of PADT from Annual Average Daily Traffic (AADT). PADT factors are calculated by:

$$\text{PADT Factor} = \text{PADT} / \text{AADT}$$

The PADT Factor data collection specification is designed to ensure a reliable estimate of PADT and AADT can be generated while minimizing the amount of data needed. This is done by collecting an adequate amount of data for each count so that a reliable monthly ADT can be estimated and that an adequate number of counts (months) are collected to properly identify the peak month and calculate a valid AADT estimate.

The specification provides requirements for the following:

- Traffic Conditions
- Count Event
- Seasonal Pattern

In general, the data obtained for a location is typical, recurring travel, with an adequate number of days for each count event, and an adequate number of events to define the seasonal pattern. If data is collected in compliance with this specification, the resulting PADT factor generated will provide reliable estimates of PADT (when using a reliable AADT estimate) at the location sampled and at other locations with similar travel characteristics.

Traffic Conditions Requirement

During the year there are changes in travel related to changes in activity and activity levels. Daily travel patterns are recurring at a particular time of the year but that pattern may change at different times of the year. These patterns drive the statistics generated to represent travel. Individual events will occur that cause deviations from the recurring pattern at that time but they have a moderate influence on monthly and annual average daily traffic statistics. The recurring pattern minimizes the impact on those statistics when a full data set is collected. As we are minimizing the data needed to generate these statistics, it is imperative that the recurring patterns be captured in the counts collected. A holiday count will be averaged with many typical days in a full data set, whereas, it will adversely impact the same statistic when using a partial data set. All data collected for PADT factor calculation must be collected when typical travel is occurring. The specifications to meet this requirement are:

- Data is not collected on holidays or holiday shoulder days (if applicable)
- Data is not collected during adverse weather (e.g. frozen precipitation, flooding)
- Data is not collected during adverse events (e.g. major accidents, temporary detours)
- Data is not collected during major social events (e.g. graduation day, sporting events)
- Data is collected with school in session if it is normally in session on that day of week
- Data is collected when schools are closed if it is normally closed on that day of week
- Data is not collected on a day that is not experiencing typical travel for that time of year

Data must be reviewed as soon as it is processed to verify that no unusual conditions occurred and that typical travel was counted. If it is determined that atypical travel was counted in a count event, there are 3 options to resolve the issue:

1. Exclude the atypical data as long as minimum count event requirements are met
2. Recount the day of week with atypical data within two weeks of the original count
3. Recount the entire count (within the seasonal pattern scheduling requirement)

This ensures that the monthly average daily traffic estimate generated from a count event is reliable. If the analyst is unsure the travel pattern is typical, a recount of the entire count should be made to verify that the typical travel pattern is being captured.

Count Event Requirement

A count event is data collected in a particular month to identify the level of monthly ADT at that location for the month. An adequate number of days of data must be collected so that a reliable monthly ADT can be estimated. Travel patterns vary by day of week and a minimum number of days must be collected to support generating the monthly ADT estimate from the count event data. In particular, weekday travel is significantly different from weekend travel at most locations and having count data representing both patterns is key to generating a valid monthly estimate. The count event ***minimum*** data requirements are:

- There must be at least one day of typical traffic data for Monday, Tuesday, Wednesday, or Thursday weekday days

- There must be at least one day of typical traffic data for Saturday or Sunday weekend days

The count event ***recommended*** data requirements are:

- Two days of typical traffic data for Monday, Tuesday, Wednesday, or Thursday weekday days
- Typical traffic data for the Friday weekday
- Typical traffic data for both Saturday and Sunday weekend days

Although an acceptable monthly ADT estimate can be generated using the minimum requirements, a count event meeting the recommended requirements will provide a monthly ADT estimate with a higher level of confidence. When resources allow, collection of a 7 day count that includes each day of the week should be collected.

Seasonal Pattern Requirement
Data is collected to support generation of two estimates, the peak monthly ADT and the annual ADT. A minimum number of count events are required to adequately approximate the seasonal pattern so these two values can be estimated properly. Count events must be collected at various times during the year so that the variation in travel experienced in the different seasons is measured. The seasonal pattern data ***minimum*** requirements are:

- There must be at least one count event in each of the four seasons:
  - Winter – December, January, and February
  - Spring – March, April, and May
  - Summer – June, July, and August
  - Fall – September, October, and November
- One of the count events must be representative of the peak travel month
- One of the count events must be representative of the lowest travel month
- If two distinctly different travel patterns occur within a season for sustained periods, then a count event measuring each pattern is required

The seasons are oriented to reflect the traditional school year to minimize the number of count events required in a season. The count event for a season must be collected at a time consistent with school operations for that season (e.g. in session in the Spring, out of session in the Summer). The last requirement is to ensure major changes in travel within a season are measured. This applies when there are distinctly different travel patterns for sustained periods of many weeks. An example of this is the Fall Color season in the mountains. Travel increases significantly during this period and is sustained for 3 to 4 weeks. The remainder of the Fall season experiences significantly less travel. On routes that experience this type of travel, a count event when Fall Colors peak and another count event outside that period are needed for the Fall season. Variations in travel occurring for shorter periods, such as Spring Break or the State Fair, do not require additional count events.

Summary
The data collection specification is designed to ensure a suitable data set is available for generating a valid PADT factor estimate. Field operations should be planned and conducted so that these requirements are met. Careful consideration of the character of travel in an area must be made to ensure the data collected is representative of typical travel. Review of the collected data must be made in a

timely manner to verify the travel measured is typical and, if not typical, a count event is recounted within the season being measured. Observation of local conditions during data collection is also a key component for ensuring the data needed is captured.

Interstate Sampling Plan

Data Sources

For prioritization P4.0, the research team were provided data from a limited number of interstate continuous and seasonal count stations. Therefore, a substantial portion of interstates were attributed PADT factors based on extrapolation or default values estimated from the AADT-based model that the research team developed.

For the prioritization P5.0 interstate sampling plan, NCDOT provided the research team with a comprehensive list of traffic survey control stations located on interstates in North Carolina. A total of 153 historic, in-service, or proposed control stations were included in the list. An additional five stations were included that are currently out-of-service due to roadway construction. Data from 25 of the stations were utilized previously for the calculation of PADT factors for the P4.0 prioritization effort in addition to data from four seasonal coverage stations, which resulted in available data for 80 interstate segments through either direct measurements or extrapolation. The four seasonal coverage count station locations used in prioritization P4.0 do not show regular intervals of data collection and data were not collected at the locations in 2015. The remaining 527 interstate segments (87%) were assigned default values for prioritization P4.0.

Table 1 provides a summary of the interstate traffic survey control stations provided by NCDOT. Five different types of traffic survey control stations are included, as follows:

1. **ATR (Automatic Traffic Recorder)** stations are fully operational embedded sensors that collect volume data continuously. Historic data is available from out-of-service ATR stations.
2. **WIM (Weight-In-Motion)** stations are fully operational embedded sensors that collect weight, vehicle classification, and volume data continuously. These stations are either no longer operational or collecting volume data only in a continuous collection. Historic data is available from out-of-service WIM stations.
3. **Radar stations** are permanent radar sites that will collect volume data continuously. The installation and working operation of these new stations needs to be verified.
4. **IC (Interstate Control)** stations have inductance loops installed in each lane and data is collected for 7 days during each annual collection cycle when deployed by the Traffic Survey Group.
5. **TC (Temporary Control)** stations are locations where data is collected using vehicle presence radar detection for 7 days during each annual collection cycle when deployed by the Traffic Survey Group. In some cases, TC stations are in the same location as historic ATR or WIM stations.

Since all data is typically available at in-service ATR and WIM stations, these stations are the least time and resource intensive for data collection. IC stations are more time and resource intensive, and TC stations are the most time and resource intensive of the station types.

NCDOT Traffic Survey Control Stations	# of Stations
Historic ATR and WIM Stations	41
In-Service ATR and WIM Stations	12
New Radar Stations	7
IC Stations	38
TC Stations	55
Total	**153**

Table 22 Summary of NCDOT Traffic Survey Control Stations on Interstates

Figure 1 shows the PADT factor application for the P4.0 prioritization effort, while Figure 2 shows the PADT factor application that is possible if the maximum number of stations are utilized for PADT factor calculation in future prioritization efforts. The maps are based on the 2014 geospatial references used for P4.0.

In Figure 1, the green points represent the 29 stations used in prioritization P4.0 with directly measured sample PADT factors, the red line segments represent the interstate segments where the calculated PADT factors were extrapolated, and the black line segments represent the interstate segments that were assigned default PADT factors. In Figure 2, the different control station types are color-coded, with green points representing in-service ATR and WIM stations, yellow points representing IC stations, blue points representing TC stations, red points representing new radar stations, and grey points representing historic (out-of-service) ATR and WIM stations. The red line segments show the interstate segments where calculated PADT factors could be extrapolated, and the black line segments depict the interstate segments that would be assigned default PADT factors.

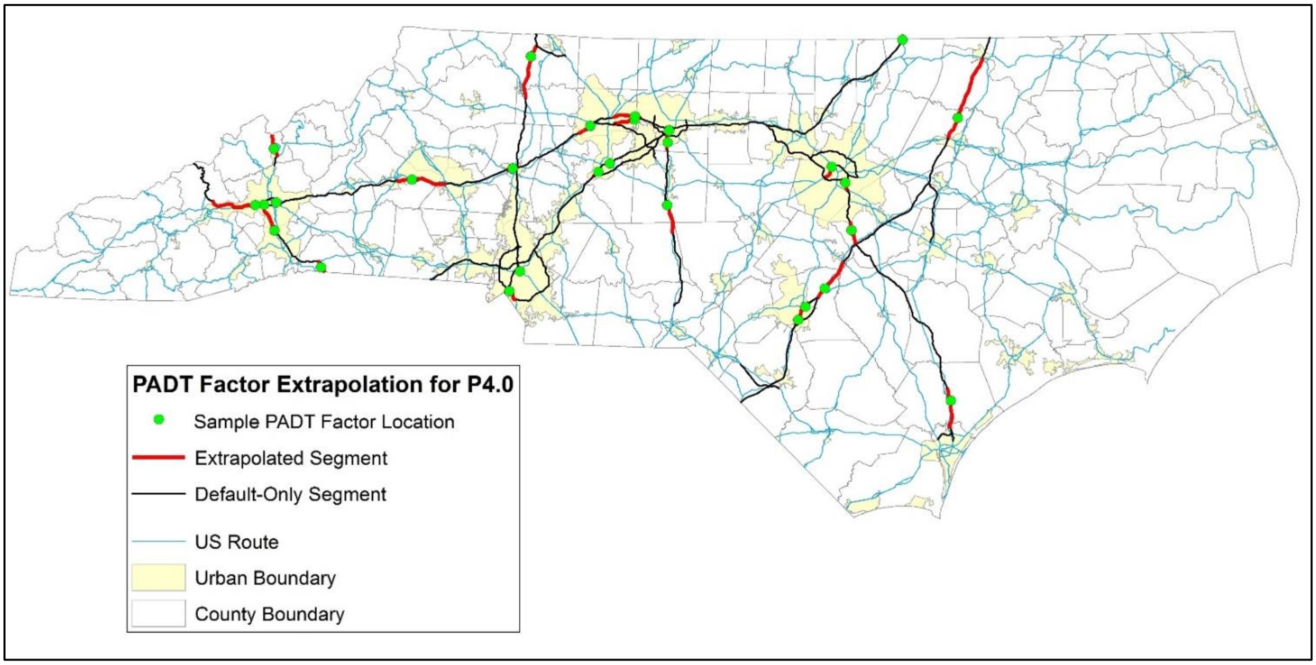


Figure 16 PADT Factor Extrapolation for P4.0 Prioritization

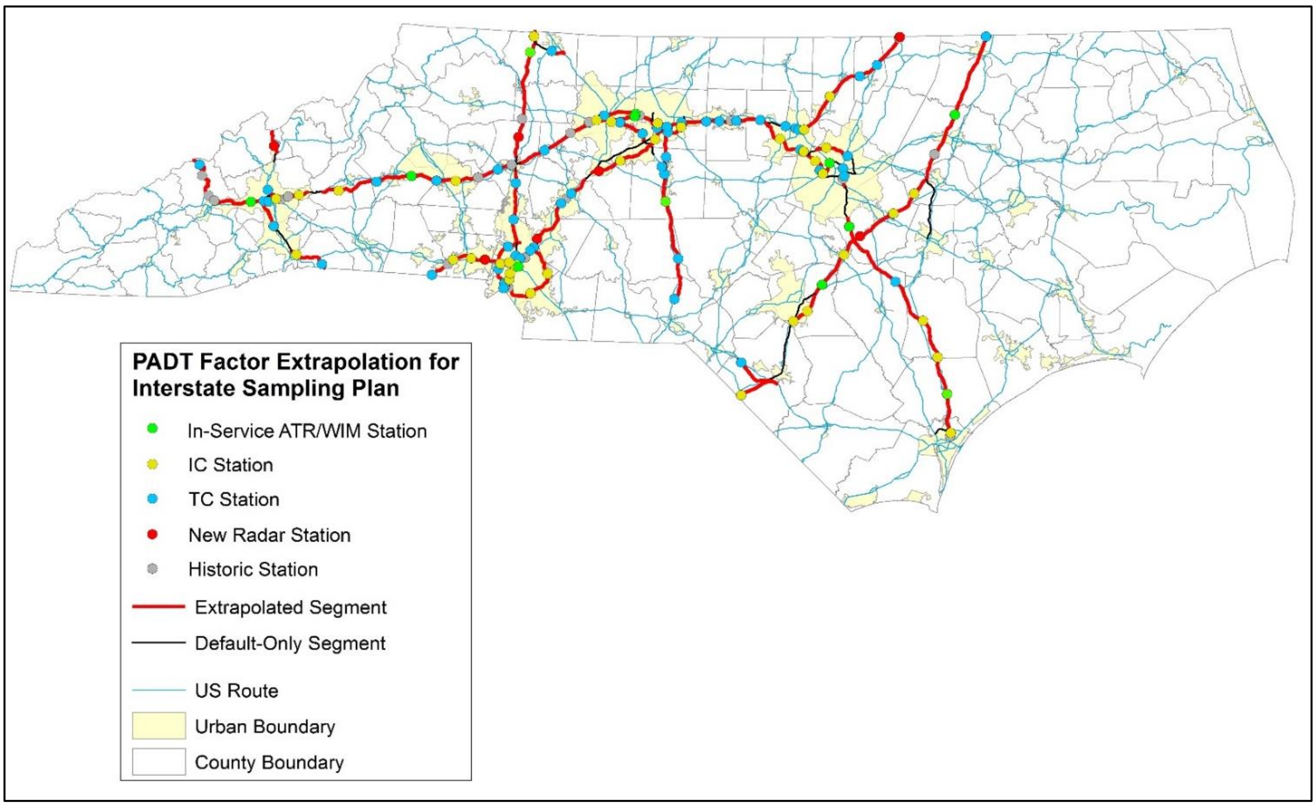


Figure 17 Potential PADT Factor Extrapolation for P5.0 Prioritization

Extrapolation Methodology

For P4.0, data extrapolation, or “gap-filling,” for interstate routes was conducted using the sample PADT factors calculated for 25 continuous and four seasonal coverage count station locations using historic data. The sample PADT factor for a continuous or seasonal coverage count station location was assigned to the nearest traffic monitoring station segment in an NCDOT-provided GIS layer that contained line segments representing all state-maintained roadways. The known PADT factors were then applied to adjacent interstate route segments in both directions until one of the following three conditions was encountered:

4. an intersection with a different interstate route,
5. an intersection with a US route, or
6. an urban/rural boundary.

For the proposed data extrapolation for interstate routes for future prioritization efforts, the extrapolation conditions were less strict. The relaxed conditions allow for more efficient, less resource-intensive interstate coverage. The urban/rural boundary condition was discarded since urban versus rural differences are accounted for by AADT. Sample PADT factors would be applied to adjacent interstate route segments in both directions until one of the following two conditions was encountered:

1. an intersection with a different interstate route only if the assigned default PADT factor is different and AADTs are significantly dissimilar on either side of the intersection, or
2. an intersection with a US route only if the assigned default PADT factor is different and AADTs are significantly dissimilar on either side of the intersection.

Interstate Sampling Levels

Taking into consideration all available stations provided by NCDOT, Figure 3 presents a series of options for sampling the stations for the purpose of generating PADT factors. The first, baseline level provides details of the prioritization P4.0 extrapolation results. For prioritization P4.0, extrapolation from 29 stations provided 18% interstate coverage. Level 1 takes advantage of existing historic count data as well as data currently being collected by in-service ATR and WIM stations. Level 2 incorporates new radar stations that will be available in the near future. Level 3 adds all available IC stations and Level 4 further adds all available TC stations. Level 4 is the most resource-intensive sampling approach and provides 75% coverage, while Level 1 utilizes all available resources without additional fieldwork and equipment installation while providing 38% coverage. A final sampling strategy, Level 5, adds additional TC stations to account for the remaining interstate segments not covered by Level 4 to achieve 100% interstate coverage for PADT factor extrapolation.

It should be noted that in some cases, extrapolation from multiple stations of the same or a different type overlaps along a common portion of an interstate. For instance, on the portion of I-40 that runs from Exit 132 to Exit 163, there are four TC stations and one historic ATR station. One TC station rather than all four stations can be used for PADT factor extrapolation purposes along the corridor. As a second example, on the portion of I-440 that runs from Exit 1A to Exit 4A, there is one in-service ATR station and one IC station. In this instance, the continuous station is preferred to the IC station for data collection, and would be used for PADT factor extrapolation purposes along the corridor.

Even the most conservative sampling approach, Level 1, provides much greater coverage than generated for P4.0, with more than double the number of interstate segments included in the extrapolation.

Additionally, it is feasible to modify any of the sampling levels to include a portion of the total available stations. Stations may also be prioritized based on sampling need. For example, it is recommended that stations located on segments with low AADTs (<20,000 VPD) be prioritized over other stations due to the recognized variability in PADT factors and current low sample size for these segments.

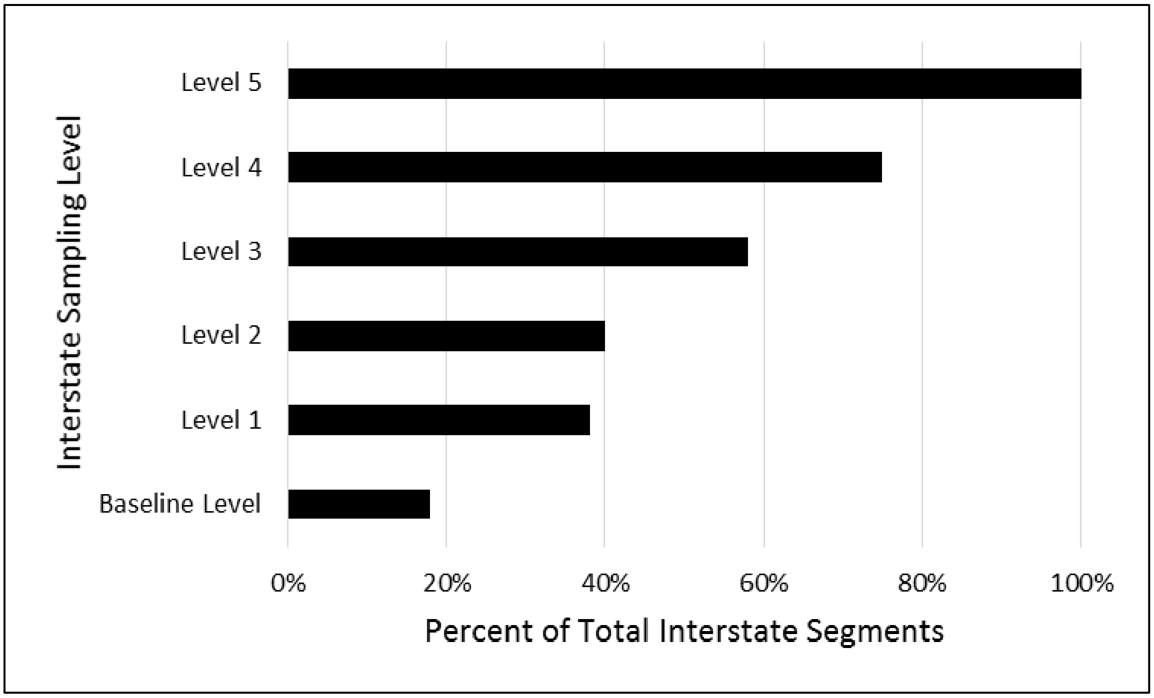


Figure 18 Coverage Provided by Interstate Sampling Levels

Final Interstate Sampling Plan

The preliminary interstate sampling approach was revised and refined based on recommendations from the NCDOT Traffic Survey Group. NCDOT Traffic Survey Group chose to adjust how they ramp balanced on interstates to eliminate unneeded TC locations and to incorporate new TC locations in the sampling plan. They decided to work backwards from the Level 5 sampling level recommendations in a selective manner to maximize utility and minimize costs associated with the data collection effort.

NCDOT Traffic Survey Group also recommended integrating an interpolation strategy for applying directly measured PADT factors along corridors between count stations rather than focusing on individual segments. The extrapolation method leaves gaps even with many sample stations and collecting additional samples to fill in the gaps is resource-intensive without maximizing the benefit of the data collection. By collecting samples along a corridor at regular intervals, interpolation can be performed between the sample PADT factors to calculate the factors for the intervening segments. Crossing routes should be flagged that should not be interpolated across due to substantial changes in AADT or their influence on travel for the corridor (i.e. significant interaction between the two routes). Extrapolation can be performed up to these routes from either side and interpolation can be performed between samples where there are no flagged crossing routes. An adequate number of samples should be collected between the flagged routes. The more interchanges between samples, the more likely there is enough change in travel to cause a change in PADT factor. The number of samples needed is not strictly a function of the number of interchanges, but also a function of the amount of interaction with crossing routes. This is reflected in the ramp volumes and a change in the type of travel (primarily urban, rural, or recreational) as indicated by the PADT factors for the samples on the crossing routes. It is recommended that all crossing interstates be flagged. Flagging other crossing route types would involve looking at travel on that route (PADT factor) and the interactions between the two (ramp volumes).

Utilizing a combination of extrapolation and interpolation allows for more efficient, less resource-intensive interstate coverage. The urban/rural boundary condition for extrapolation would be discarded since urban versus rural differences are accounted for by AADT. Corridors with low- and mid- range AADTs should be sampled carefully due to the high variability observed in the PADT factors for these types of locations in the continuous count data. Conversely, excessive sampling on corridors with high-range AADTs are less critical due to the low variability observed in the PADT factors for these types of locations in the continuous count data. Locations where there are large changes in AADT should be break points in the interpolation process which affects sampling. A summary of possible interpolation and extrapolation scenarios is provided in Appendix A.

Through these modifications, a better Level 4 sampling plan was designed that more efficiently incorporated additional interstate segments. In additional to the count stations previously mentioned, this plan incorporates HERE.com sensor stations located on I-40/I-440 and I-540 and North Carolina Toll Authority stations located on I-540. The revised sampling plan was applied to 2015 reference interstate segments which increases the segment total from 607 to 636 segments for the interstate network. A summary of the preliminary continuous and sample station utilization for P5.0 is provided in Table 2.

<table>
<tr><th>Interstate PADT Factor Counts</th><th>Stations Available</th><th>Stations Used</th><th colspan="2">Segments Covered</th></tr>
<tr><td>Continuous Counts</td><td>93</td><td>55</td><td rowspan="2">117</td><td rowspan="2">18%</td></tr>
<tr><td>Short Term (Sample) Counts</td><td>64</td><td>62</td></tr>
<tr><td>Extrapolated/Interpolated Counts</td><td colspan="2"></td><td>519</td><td>82%</td></tr>
<tr><td colspan="3" align="right">Total</td><td>636</td><td>100%</td></tr>
</table>

Table 23 Preliminary Interstate Sampling Plan Coverage for P5.0

Data Collection

As previously detailed, several count data sources were used to generate PADT factors for the interstate network for P5.0. These sources included continuous and sample count data collected by NCDOT Traffic Survey Group, as well as continuous count data collected by HERE.com sensor stations and North Carolina Toll Authority ATRs. The data collected from the HERE.com sensor stations were different in character from the other data sources, and required additional evaluation by the ITRE research team in terms of their data completeness, potential errors/outliers, and data coverage. A summary of the HERE.com data evaluation is provided in Appendix C.

Interstate PADT Factor Calculation

Continuous or sample data were collected from 117 interstate count stations. However, two PADT factors generated from continuous counts on I-540 were dropped from further consideration due to being significantly higher than expectation from probable data error. Eight radar continuous count stations that were installed in 2016 failed to capture a full year of data. Six of these stations were treated as sample stations since they captured data from at least one week in each of the four seasons. PADT factors could not be generated for two radar stations that failed to capture data from at least one week in each season. Continuous counts provided for one station on I-40 require further evaluation and were not used to generate a PADT factor. Therefore, PADT factors were calculated for 112 interstate count stations based on data requirements.

Interstate PADT Factor Defaults

For prioritization P4.0, interstate default PADT factors were developed using continuous count data to apply to roadway segments that could not be assigned measured PADT factors either with data collected at a given roadway location or through extrapolation. Interstate segments were classified by Annual Average Daily Traffic (AADT) level using upper boundary, lower boundary, and middle range AADT thresholds that were determined by an analysis of data trends and natural breakpoints in the continuous count data. A linear regression equation that estimates the PADT factor from AADT was generated using the middle range AADT values from the continuous count data provided by NCDOT. The dependent variable was the PADT factor for the 19 continuous count stations in the middle range. Default PADT factor values for middle range AADTs were estimated from the resulting linear equation. For segments with AADTs outside the middle range, an upper boundary default PADT factor was assigned to high AADT values, and a lower boundary default PADT factor was assigned to low AADT values.

The analysis was limited by the small sample size of interstate continuous count stations available. Data from 19 stations were used in the development of the linear model for middle range AADT values and a total of 26 stations were considered in the analysis. Figure 4 provides a graphical representation of field-measured values and the three-regime model used for prioritization P4.0.

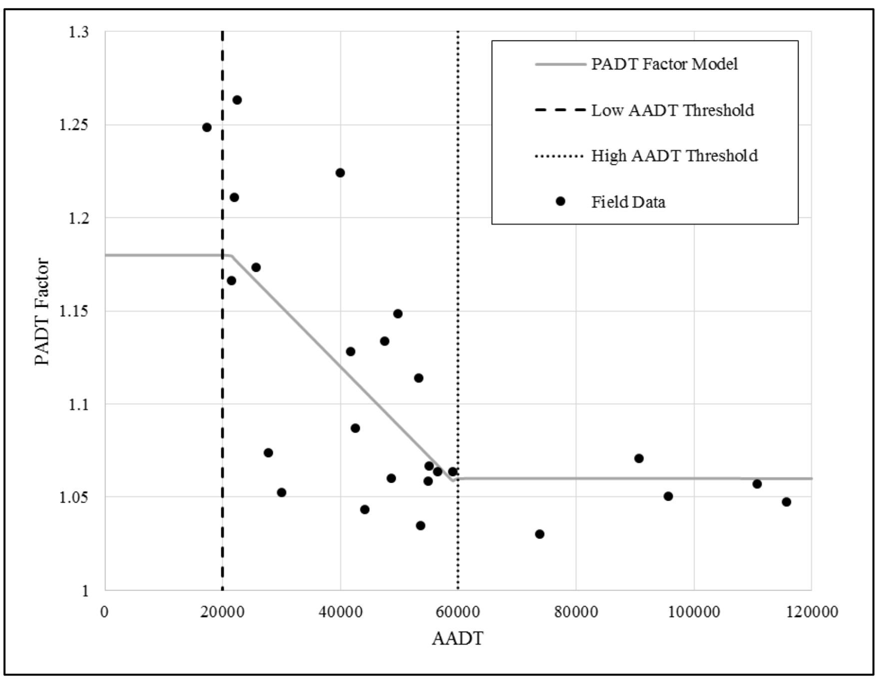


Figure 19 P4.0 Interstate PADT Factor Model as a Function of AADT

For P5.0, the interstate default PADT values were reevaluated using the larger sample of stations available. PADT values generated from continuous and sample counts were evaluated together, and their spread in relation to AADT resembles the spread of the non-interstate PADT factors generated for P4.0. Upper boundary, lower boundary, and middle range AADT thresholds for Interstate routes were determined by an analysis of data trends and natural breakpoints in the continuous count data. Table 3 presents the proposed AADT thresholds for Interstate routes. Table 4 provides the sample sizes of the PADT factors by AADT level for the calculation of Interstate default PADT factors. A linear regression equation that estimates the PADT factor from AADT was generated using PADT factors and AADT values derived from the sample and continuous count data. Default PADT factor values for middle range AADTs were estimated from the resulting linear equation shown in Table 5. For segments with AADTs outside the middle range, an upper boundary default PADT factor was assigned to high AADT values, and a lower boundary default PADT factor was assigned to low AADT values. The updated three-regime model is provided in Figure 5.

Route Type	Low AADT	Middle Range AADT	High AADT
Interstate	<20,000	20,000-100,000	>100,000

Table 24 Interstate AADT Threshold Values

Route Type	Low AADT	Middle Range AADT	High AADT
Interstate	14	87	11

Table 25 Sample Size of PADT Factors by AADT Level for Calculation of Interstate Defaults

Route Type	Low AADT	Middle Range AADT	High AADT
Interstate	1.13	Varies from 1.05 to 1.13 based on the following equation: 1.1441662+(-0.00000091566*AADT)	1.05

Table 26 Recommended PADT Default Factors by AADT Level for Interstate Routes

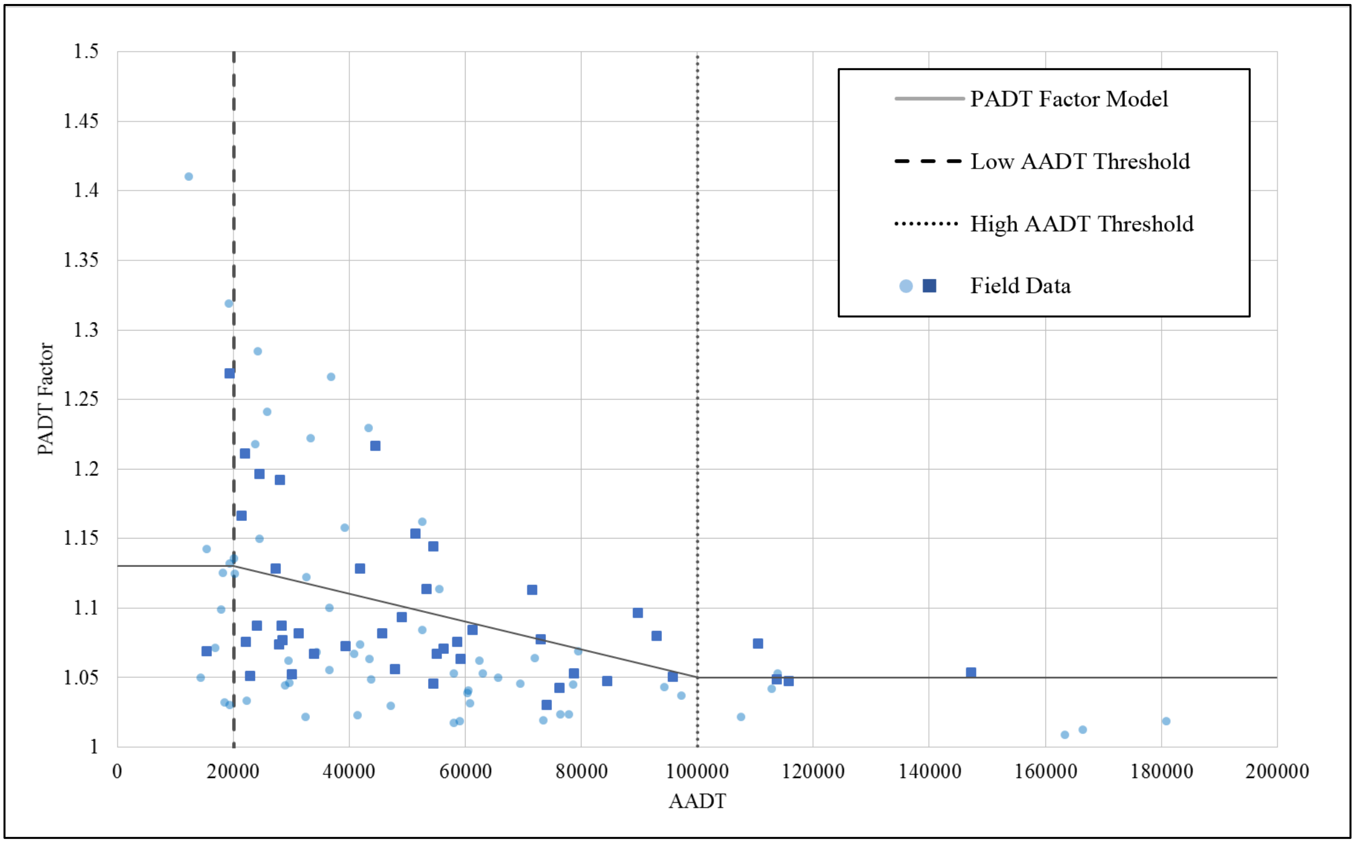


Figure 20 P5.0 Interstate PADT Factor Model as a Function of AADT – light blue circles represent sample data and dark blue squares represent continuous data

Application of Interstate PADT Factors to Roadway Network

PADT factors were calculated from continuous or sample counts for 112 interstate count stations based on data requirements. PADT factors from 111 stations were applied to the interstate roadway network using interpolation or extrapolation; one PADT factor from a sample station located on the US-264 corridor was not included. For interpolated segments, either a straight line or change rate method was used depending on the variability in AADT on the intervening segments. A summary of the final interstate sampling plan coverage for P5.0 is provided in Table 6 and visualized in Figure 6.

Interstate PADT Factor Counts	Stations Available	Stations Used	Segments Covered	
Continuous Counts	93	44	111	18%
Short Term (Sample) Counts	68	62		
Extrapolated Counts			204	32%
Interpolated Counts			321	50%
		Total	**636**	**100%**

Table 27 Final Interstate Sampling Plan Coverage for P5.0

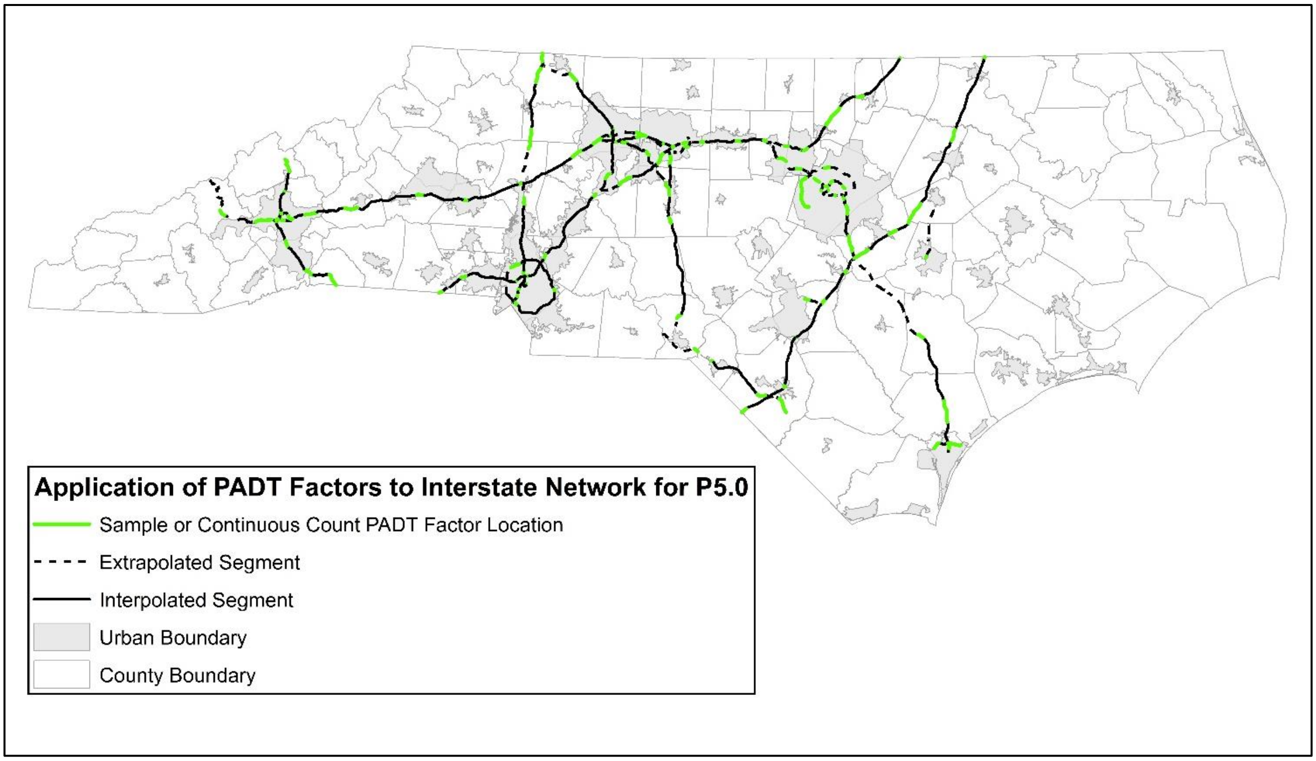


Figure 21 Application of PADT Factors to Interstate Network for P5.0 Prioritization

A summary of the recommended PADT factors for the interstate network for P5.0 is provided in Figure 7. The highest calculated PADT factor for interstates was 1.43, while the majority of roadway segments received a PADT between 1.01-1.19.

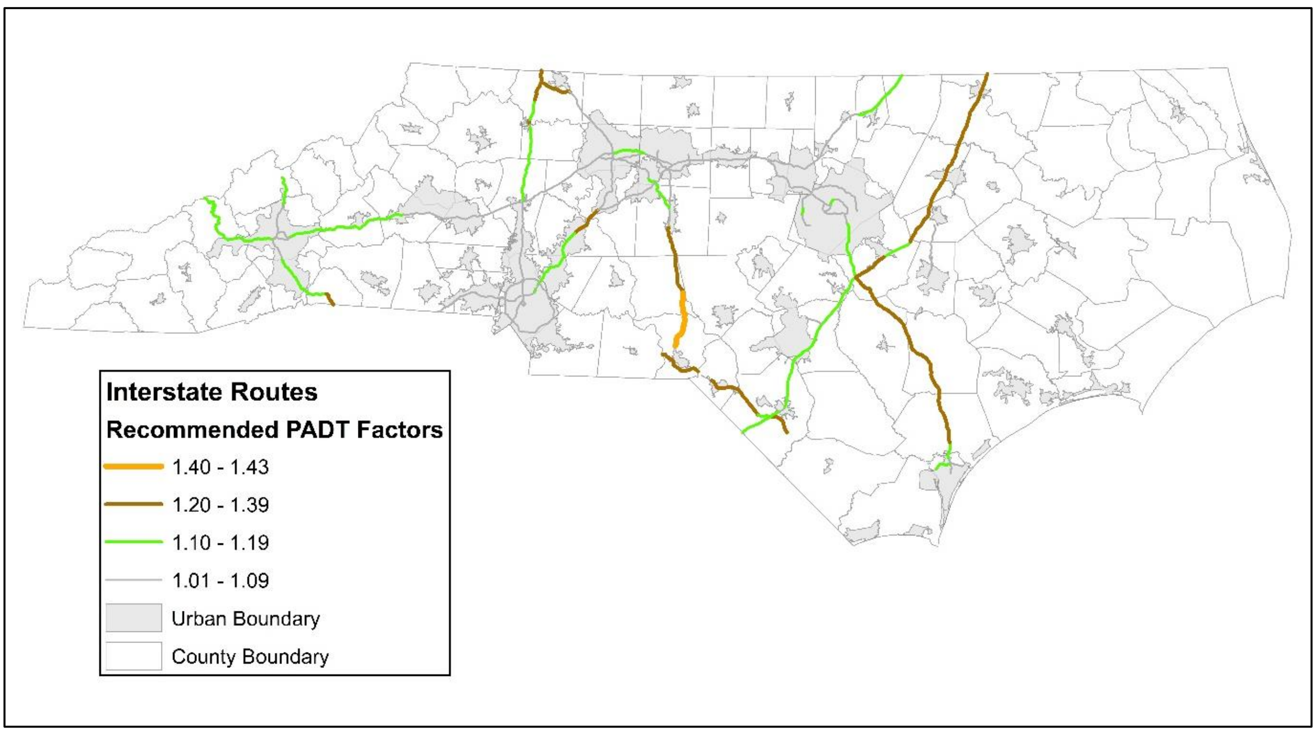


Figure 22 Recommended PADT Factors for Interstate Routes for P5.0 Prioritization

P6.0 PRIORITIZATION METHODOLOGY

Sampling Plan for North Carolina Counties with Limited Data for PADT Factor Calculation

For prioritization P4.0, the research team were provided data from a limited number of seasonal count stations to generate PADT factors for routes in North Carolina. Out of North Carolina's 100 counties, thirteen counties did not have adequate data to generate any PADT factors and four counties had adequate data to generate only one PADT factor per county (Table 7). Therefore, nearly all routes in these counties were attributed default values estimated from the AADT-based model that the research team developed. A limited number of segments in a few of the 17 counties were attributed in P4.0 using PADT factors calculated for routes in adjacent counties with adequate data samples. These segment totals are provided by relevant county in Table 8.

County Name	Count of P4.0 Factors
BERTIE	0
FRANKLIN	0
GATES	0
HALIFAX	0
HERTFORD	0
HOKE	0
JACKSON	0
JONES	0
MOORE	0
PAMLICO	0
SCOTLAND	0
VANCE	0
ROBESON	0
LENOIR	1 – NC Route
PERSON	1 – NC Route
POLK	1 - Interstate
WARREN	1 - Interstate

Table 28 Summary of NC Counties with Limited or No Data to Generate PADT Factors

County Name	Count of P4.0 Segments Attributed Through Extrapolation from Adjacent County
BERTIE	22
FRANKLIN	9
GATES	9
HALIFAX	34
HOKE	4
JACKSON	18
JONES	18
LENOIR	31
MOORE	30
PAMLICO	6
PERSON	38
POLK	14
ROBESON	15
SCOTLAND	1

VANCE	1
WARREN	4

Table 29 Summary of P4.0 Segment Extrapolation for NC Counties with Limited or No Data to Generate PADT Factors

For prioritization P6.0, the research team developed a sampling plan for the 17 NC counties with limited or no data for generating PADT factors. Unlike the P5.0 sampling plan developed by the research team for interstates, limited P4.0 PADT factors were available to provide evidence and support for extrapolation and interpolation decisions. However, nine PADT factors that were calculated for P4.0 and located in counties adjacent to the 17 NC counties included in the sampling plan were used for extrapolation or interpolation purposes which affects 31 segments total.

<u>Data Sampling, Extrapolation, and Interpolation Methodology</u>

For P4.0, data extrapolation, or "gap-filling," for US routes was conducted using the sample PADT factors calculated for 1,065 seasonal coverage count station locations using historic data. Data extrapolation for NC routes was conducted using the sample PADT factor calculated for 1,134 seasonal coverage count station locations using historic data. The sample PADT factor for a seasonal coverage count station location was assigned to the nearest traffic monitoring station segment in an NCDOT-provided GIS layer that contained line segments representing all state-maintained roadways. The known PADT factors were then applied to adjacent route segments in both directions until one of the following three conditions was encountered:

For US routes:

1. an intersection with an Interstate route,
2. an intersection with another US route, or
3. an urban/rural boundary.

For NC routes:

5. an intersection with an Interstate route,
6. an intersection with a US route,
7. an intersection with another NC route, or
8. an urban/rural boundary.

As previously detailed, a combination of interpolation and extrapolation will be utilized for future prioritization efforts to allow for more efficient, less resource-intensive route coverage. For the P6.0 sampling plan, urban NC route and rural US and NC route corridors should be sampled carefully due to the variability observed in the PADT factors for these types of locations in the historic seasonal coverage count data. Locations where there are large changes in AADT should be break points in the interpolation process which affects sampling.

Sample PADT factors would be applied to adjacent route segments in both directions until one of the following three conditions is encountered:

1. an intersection with an interstate route only if the assigned default PADT factor is different and AADTs are significantly dissimilar on either side of the intersection, or
2. an intersection with a US route only if the assigned default PADT factor is different and AADTs are significantly dissimilar on either side of the intersection.

3. an intersection with an NC route only if the assigned default PADT factor is different and AADTs are significantly dissimilar on either side of the intersection.

Using a combination of extrapolation and interpolation in the construction of an US and NC route sampling plan for the 17 counties in NC with limited or no data for generating PADT factors, 644 seasonal coverage count stations should be sampled. This total includes 266 stations located on US routes and 378 stations located on NC routes. For the US and NC route sampling plan, nine PADT factors that were calculated for P4.0 were used for extrapolation or interpolation purposes which affects 31 segments total (Table 9). A summary of possible interpolation and extrapolation scenarios is provided in Appendix B.

Tables 10-11 provide a summary of the segment totals by county, route type, and method for deriving or applying PADT factors – count (segment should be sampled and a PADT factor should calculated for the segment), extrapolate (PADT factor from a sampled station should be extrapolated to the segment), or interpolate (PADT factor from a sampled station should be interpolated to the segment).

P4.0 Data Sources for US and NC Routes	
Number of P4.0 Factors Used	9
Number of Segments Affected	31

Table 30 Summary of P4.0 Data Sources Used for US and NC Route Sampling Plan

	US and NC Routes					
County	**Count**		**Extrapolate**		**Interpolate**	
BERTIE	40	48%	11	13%	32	39%
FRANKLIN	54	53%	5	5%	43	42%
GATES	19	33%	3	5%	36	62%
HALIFAX	73	49%	54	36%	23	15%
HERTFORD	44	52%	26	31%	15	18%
HOKE	12	27%	10	23%	22	50%
JACKSON	47	57%	2	2%	33	40%
JONES	23	58%	1	3%	16	40%
LENOIR	38	32%	20	17%	59	50%
MOORE	68	44%	26	17%	59	39%
PAMLICO	16	50%	4	13%	12	38%
PERSON	20	25%	3	4%	57	71%
POLK	15	31%	6	13%	27	56%
ROBESON	86	38%	42	19%	98	43%
SCOTLAND	41	39%	21	20%	44	42%
VANCE	26	34%	8	11%	42	55%
WARREN	22	37%	10	17%	28	47%

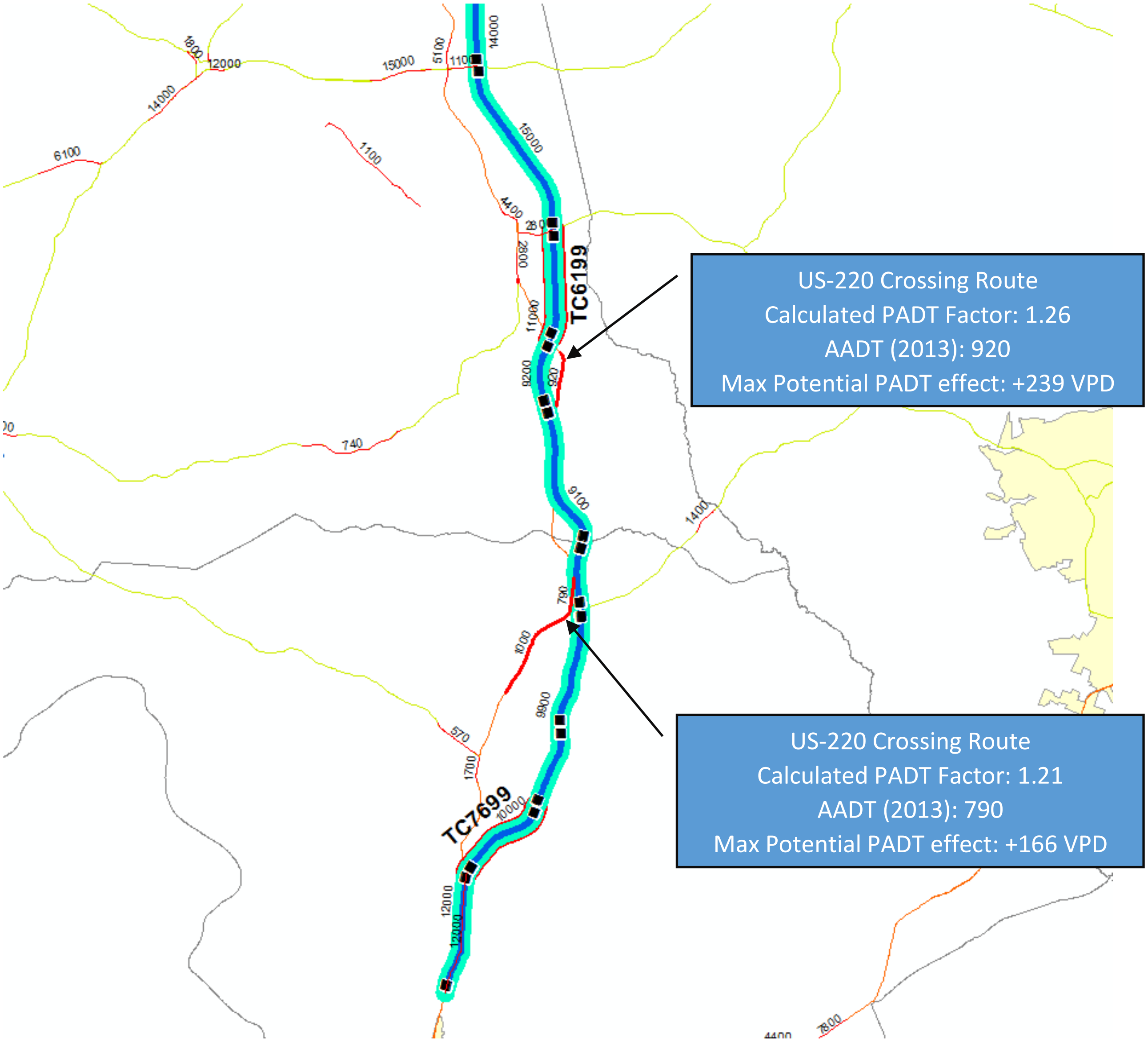
Table 31 Summary of Segment Totals by County, Route Type, and Method for Deriving or Applying PADT Factors for P6.0

	Interstate, US, and NC Routes					
	Count		Extrapolate		Interpolate	
Interstate	6	16%	3	8%	29	76%
HALIFAX	0	0%	0	0%	5	100%
POLK	1	50%	0	0%	1	50%
ROBESON	3	16%	3	16%	13	68%
VANCE	1	13%	0	0%	7	88%
WARREN	1	25%	0	0%	3	75%
US Routes	266	40%	97	15%	295	45%
BERTIE	14	45%	5	16%	12	39%
FRANKLIN	23	58%	3	8%	14	35%
GATES	8	29%	1	4%	19	68%
HALIFAX	23	44%	16	31%	13	25%
HERTFORD	17	49%	8	23%	10	29%
HOKE	7	30%	9	39%	7	30%
JACKSON	30	63%	2	4%	16	33%
JONES	9	56%	0	0%	7	44%
LENOIR	11	25%	6	14%	27	61%
MOORE	22	40%	10	18%	23	42%
PERSON	10	22%	3	7%	32	71%
POLK	5	31%	0	0%	11	69%
ROBESON	22	44%	7	14%	21	42%
SCOTLAND	30	36%	17	20%	36	43%
VANCE	20	37%	3	6%	31	57%
WARREN	15	39%	7	18%	16	42%
NC Routes	378	43%	155	18%	351	40%
BERTIE	26	50%	6	12%	20	38%
FRANKLIN	31	50%	2	3%	29	47%
GATES	11	37%	2	7%	17	57%
HALIFAX	50	51%	38	39%	10	10%
HERTFORD	27	54%	18	36%	5	10%
HOKE	5	24%	1	5%	15	71%
JACKSON	17	50%	0	0%	17	50%
JONES	14	58%	1	4%	9	38%
LENOIR	27	37%	14	19%	32	44%
MOORE	46	47%	16	16%	36	37%
PAMLICO	16	50%	4	13%	12	38%
PERSON	10	29%	0	0%	25	71%
POLK	10	31%	6	19%	16	50%
ROBESON	64	36%	35	20%	77	44%
SCOTLAND	11	48%	4	17%	8	35%
VANCE	6	27%	5	23%	11	50%
WARREN	7	32%	3	14%	12	55%

Table 32 Summary of Segment Totals by County, Route Type, and Method for Deriving or Applying PADT Factors for P6.0

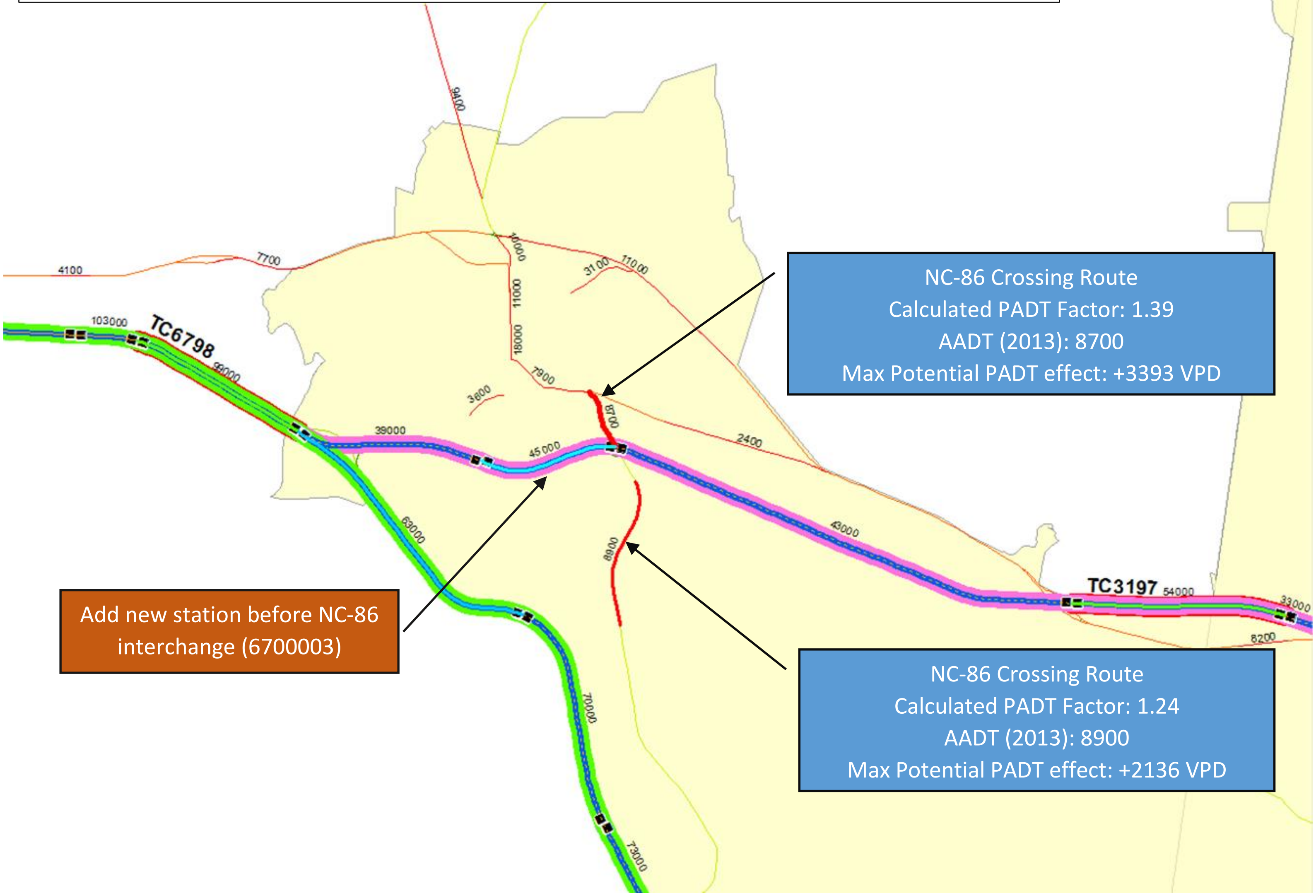
APPENDIX A: EXTRAPOLATION AND INTERPOLATION EXAMPLES FOR INTERSTATES

Example 1: Interpolation Across A Low Interaction Crossing Route



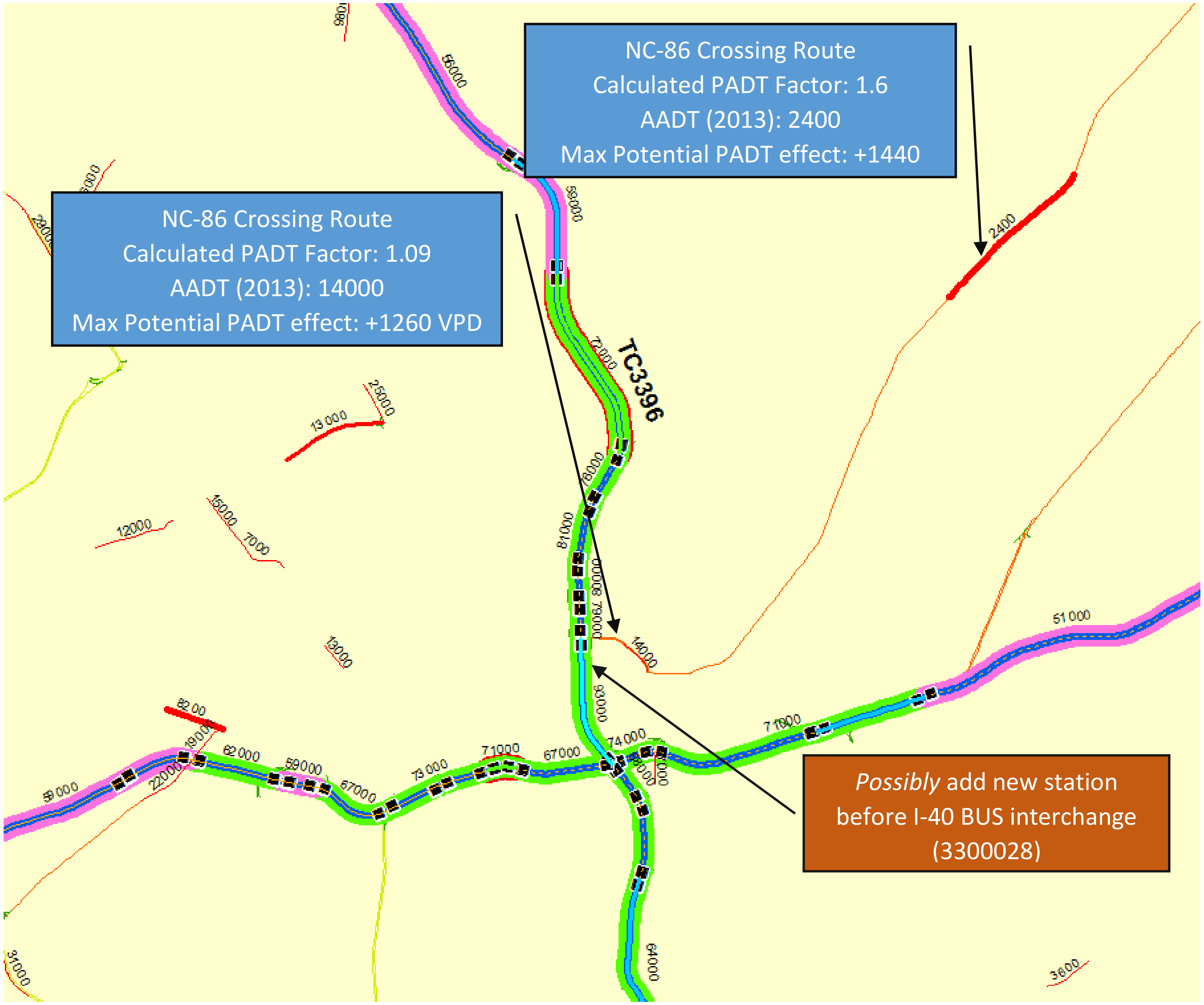
In Example 1, interpolation would be performed between two portable radar stations (TC6199 [6100077], TC7699 [7603503]) on I-73 in Richmond County because the seasonal interaction with US-220 as a crossing route does not appear to be substantial according to the calculated PADT factors.

Example 2: Add Station Due to Possible Seasonal Interaction Supported by Calculated PADT



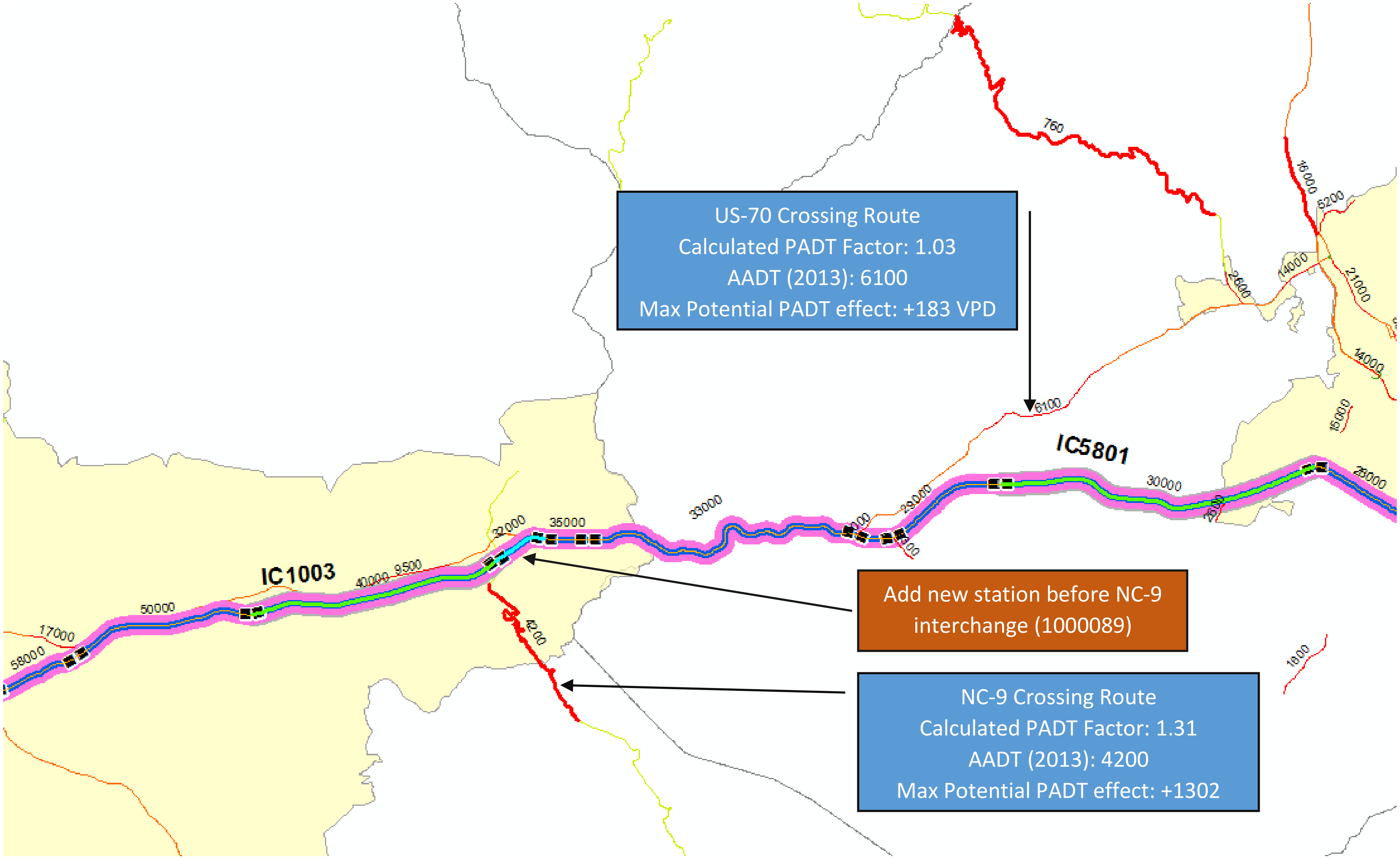
In Example 2, a new station would be added on I-85 in Orange County to the west of the NC-86 interchange due to possible seasonal interaction with NC-86 according to the calculated PADT factors.

Example 3: Low Priority Station Addition with Possible Seasonal Interaction Supported by Calculated PADT Factors



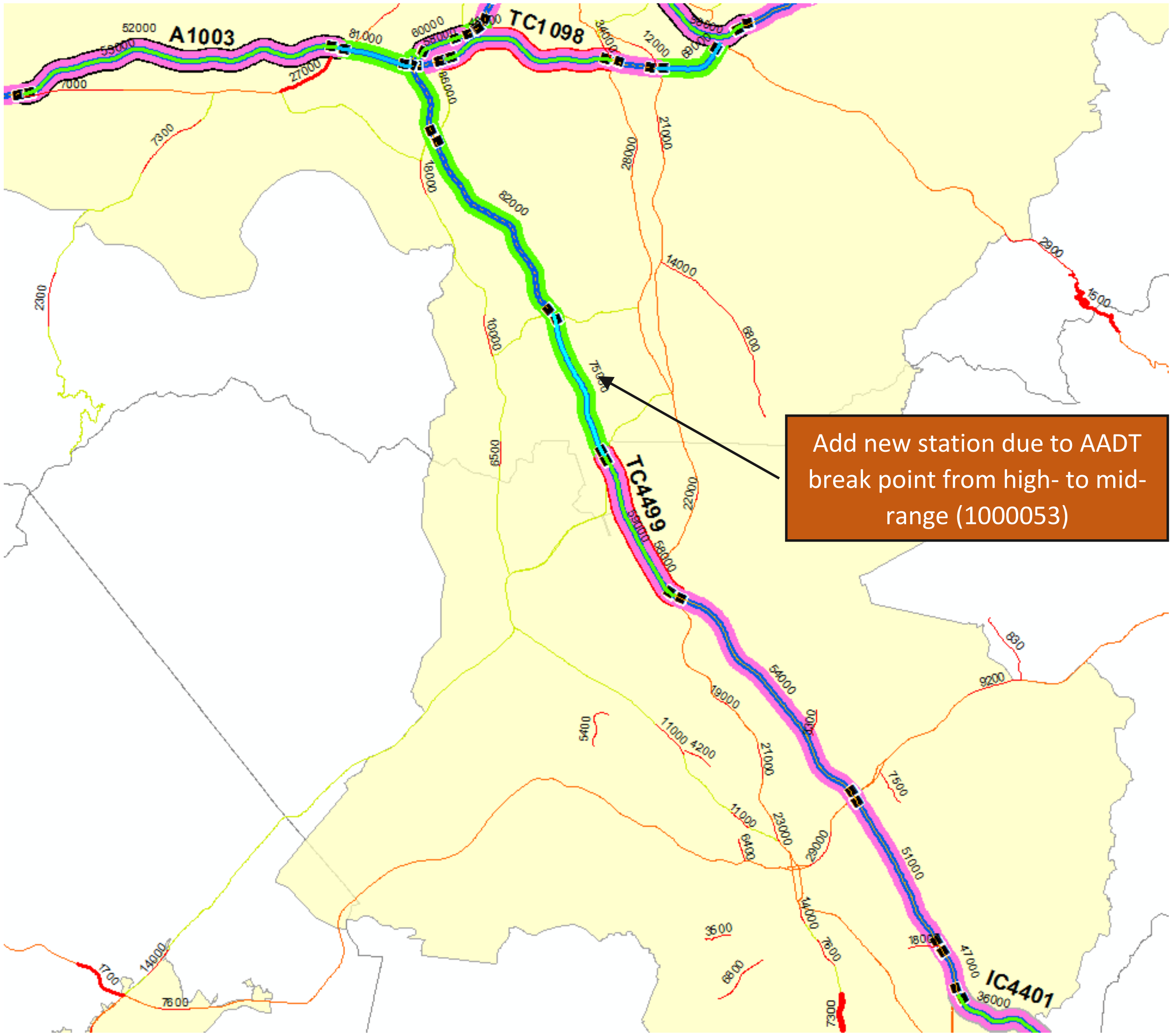
In Example 3, a new station could *possibly* be added on US-52 in Forsyth County to the north of the I-40 Business interchange due to possible seasonal interaction with NC-86 according to the calculated PADT factors. However, this would not be considered a high priority station addition because of the high-range AADTs on the corridor.

Example 4: Substantial and Marginal Seasonal Interaction Supported by Calculated PADT Factors



In Example 4, a new station would be added on I-40 in Buncombe County to the east of the NC-9 interchange due to possible seasonal interaction with NC-9 according to the calculated PADT factors. Interpolation would be performed between the new station and IC5801 (5800034) since the US-70 crossing route appears to have a marginal seasonal interaction with I-40 based its calculated PADT factors.

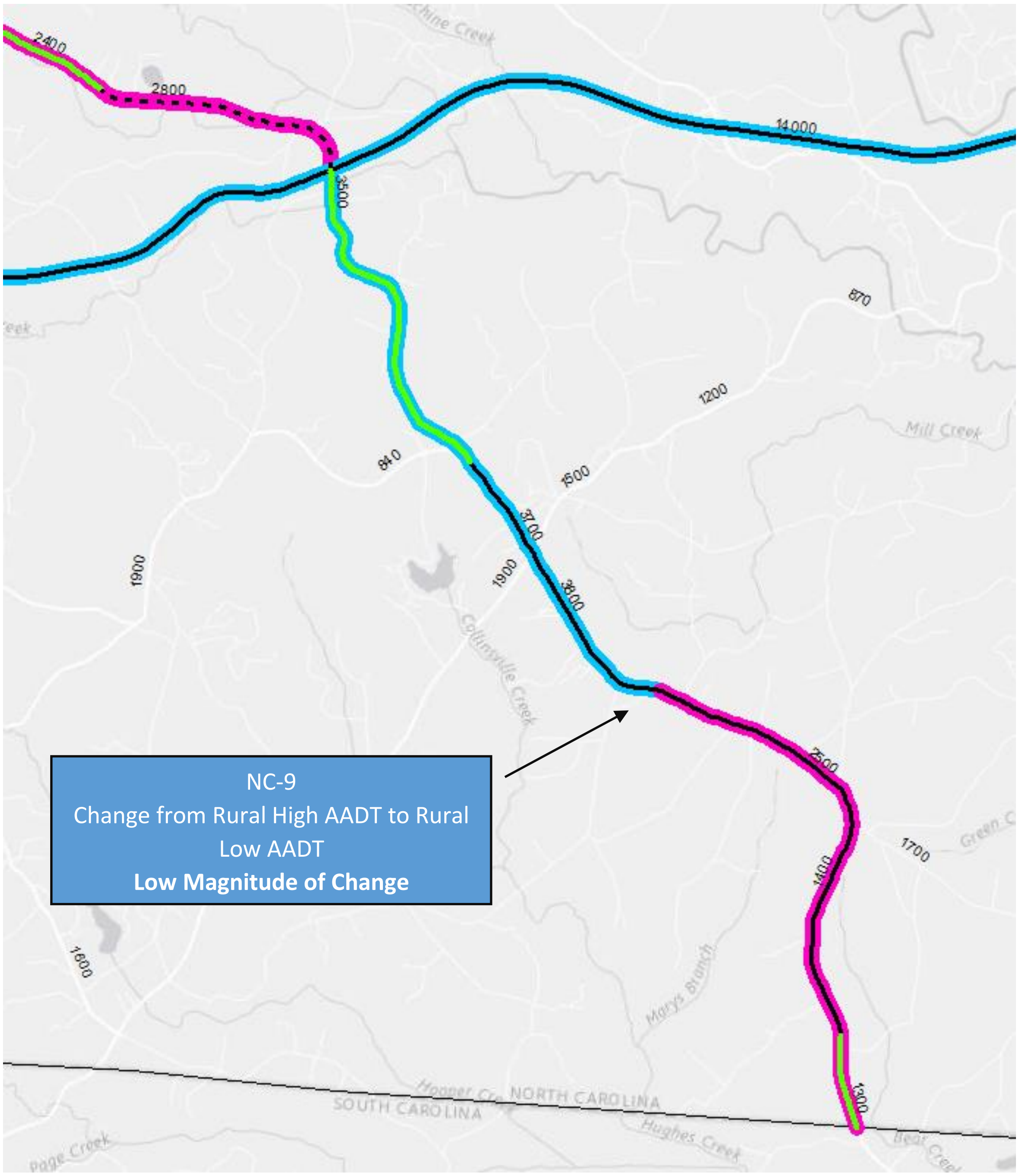
Example 5: Add Station Due to AADT Break Point



In Example 5, a new station would be added on I-26 in Buncombe County to the north of the NC-280 interchange due to a severe change in AADT, i.e. a break point from high- to mid-range AADTs. The calculated PADT factor generated from the new station could be extrapolated north along the corridor to the I-40 interchange since there appears to be no substantial interaction with crossing routes.

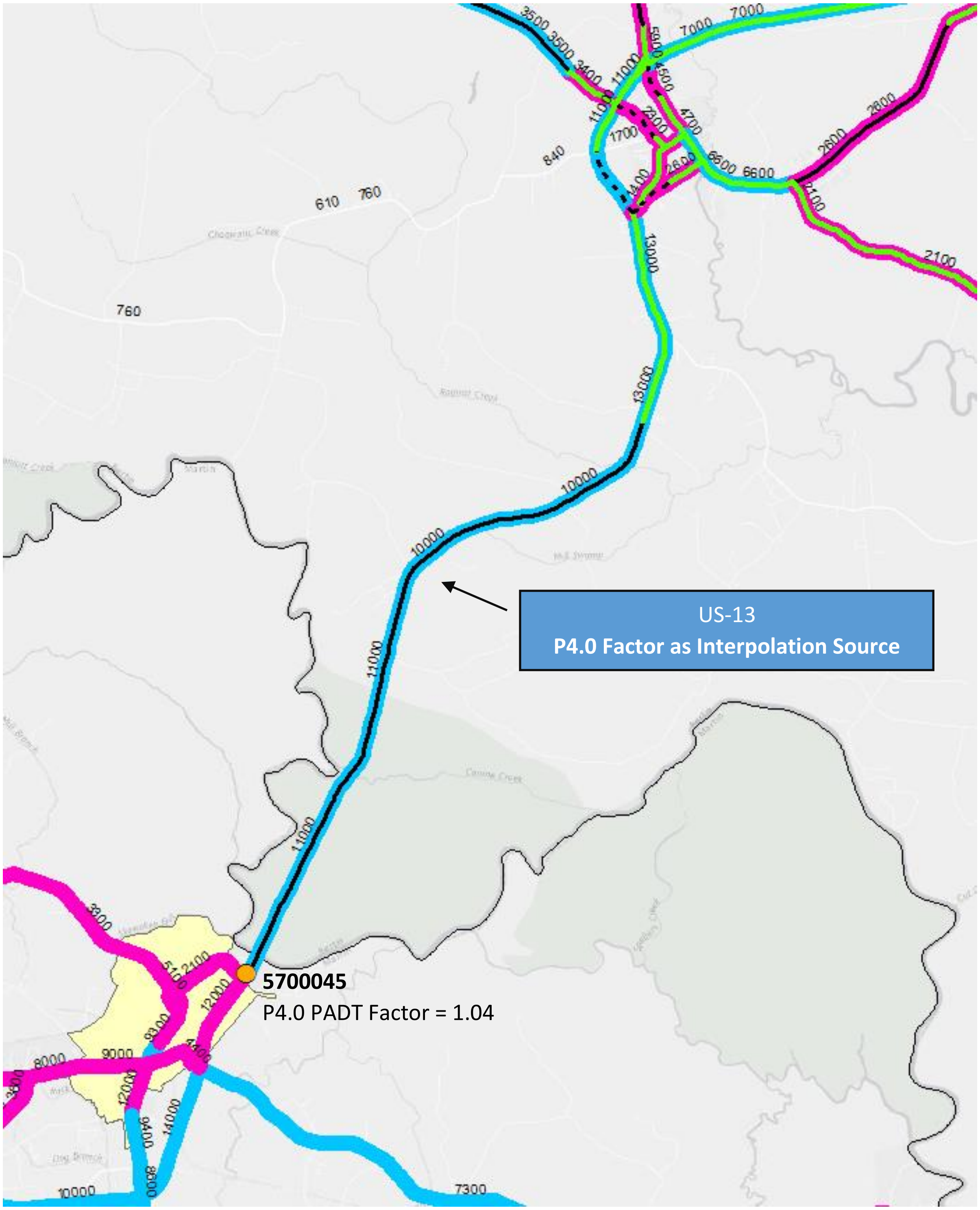
APPENDIX B: EXTRAPOLATION AND INTERPOLATION EXAMPLES FOR US AND NC ROUTES

Example 1: Interpolation across Low Magnitude Change from High to Low AADT



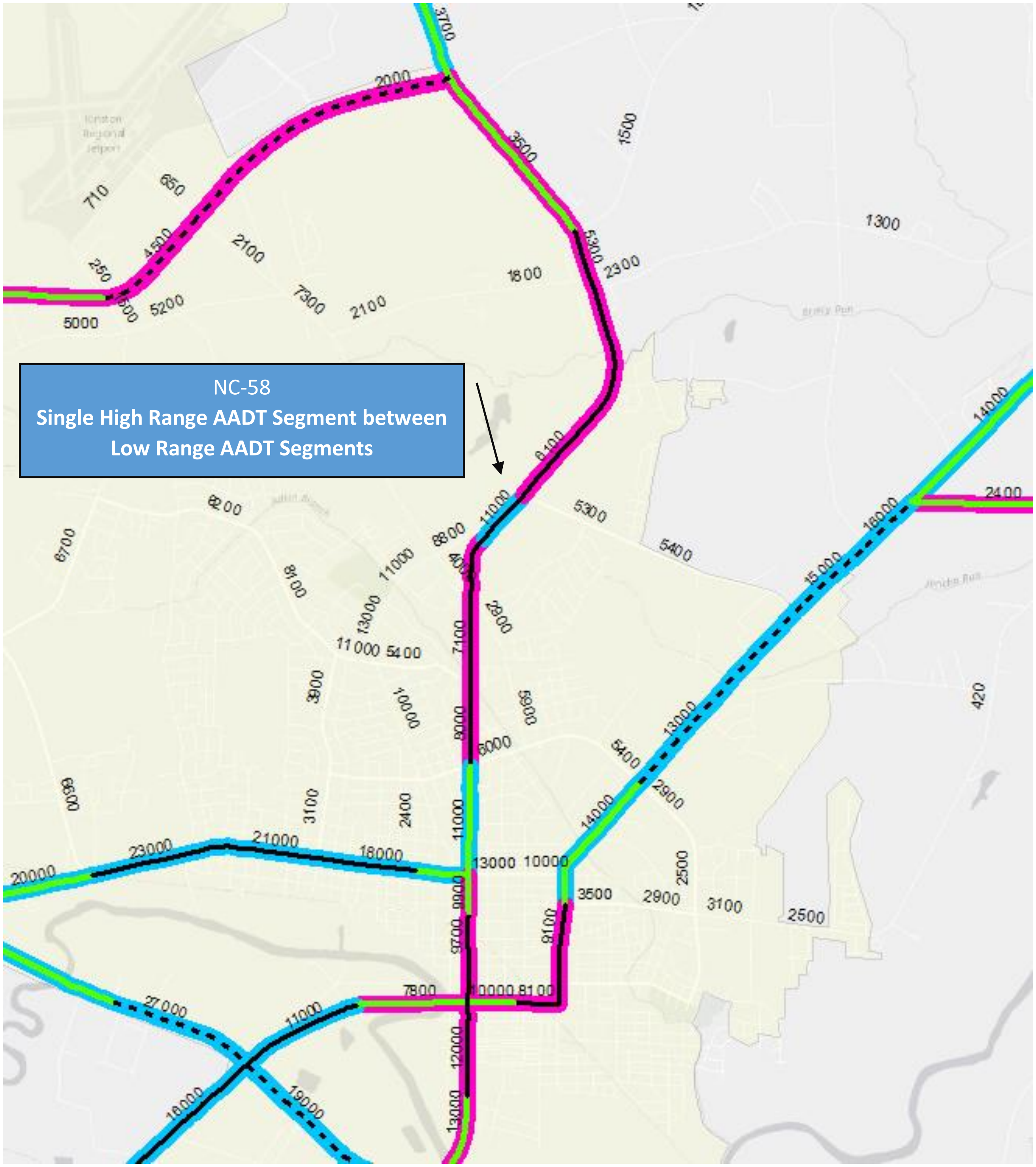
In Example 1, interpolation would be performed between two sampled seasonal coverage count stations (7409001, 7400045) on NC-9 in Polk County because of the low magnitude of change between the two breakpoint segments. Interpolation using a factor change rate (i.e. factor change/1000 AADT) seems appropriate in this case.

Example 2: P4.0 Factor for Interpolation



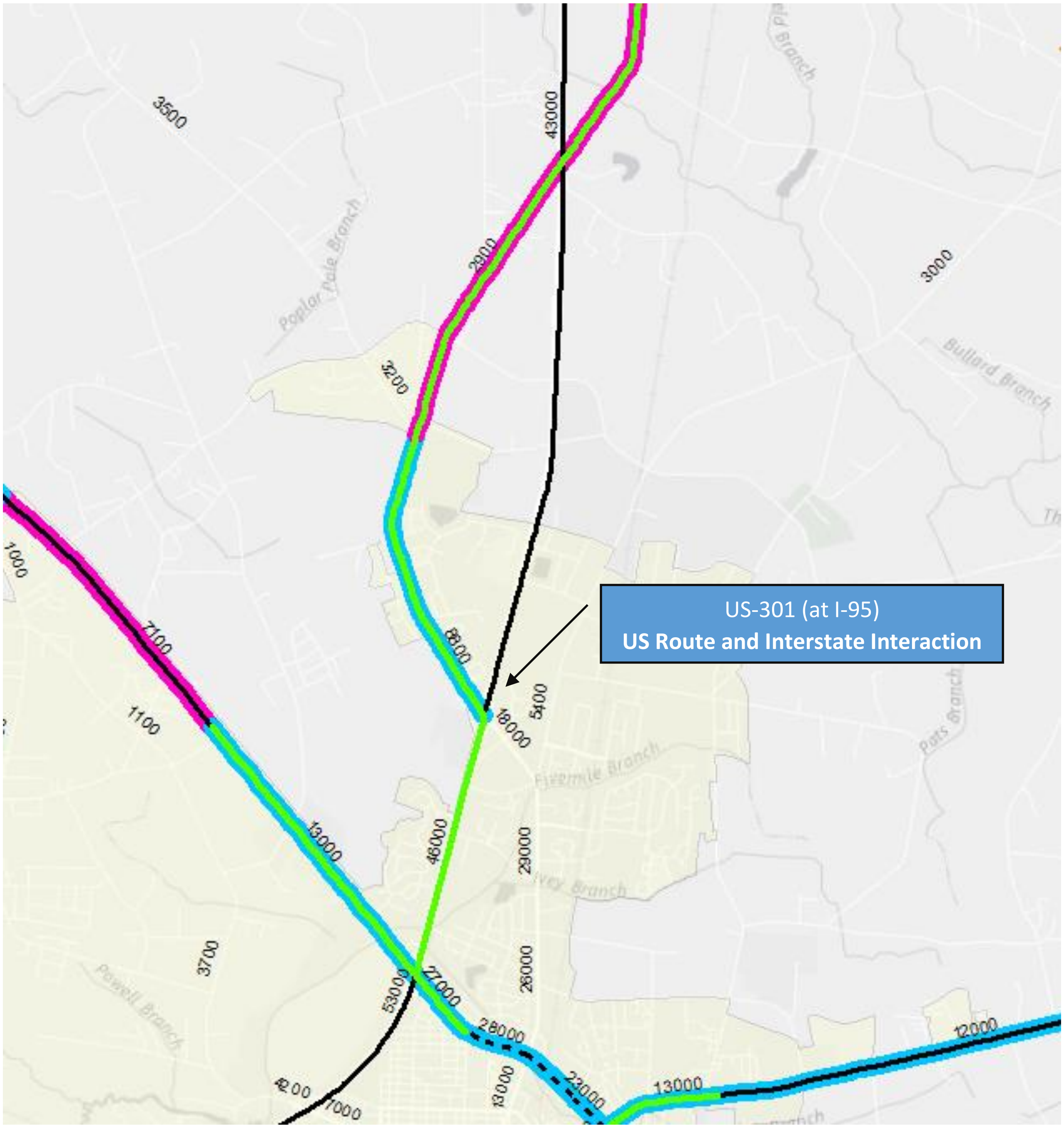
In Example 2, interpolation would be performed between one sampled seasonal coverage count station (700043) and a station with a previously calculated P4.0 factor (5700045; P4.0 factor of 1.04) on US-13 in Bertie County.

Example 3: Single High Range AADT Segment between Low Range AADT Segments



In Example 3, interpolation would be performed between two sampled seasonal coverage count stations (5300003, 5300014) on NC-58 in Lenoir County across a single intervening urban high range AADT segment.

Example 4: US Route and Interstate Interaction



In Example 4, both US-301 segments between intersections with I-95 should be sampled (7703408, 7700162) in Robeson County due to the difference in AADT range between the two segments resulting from their interaction with I-95.

APPENDIX C: HERE.COM VOLUME DATA EVALUATION

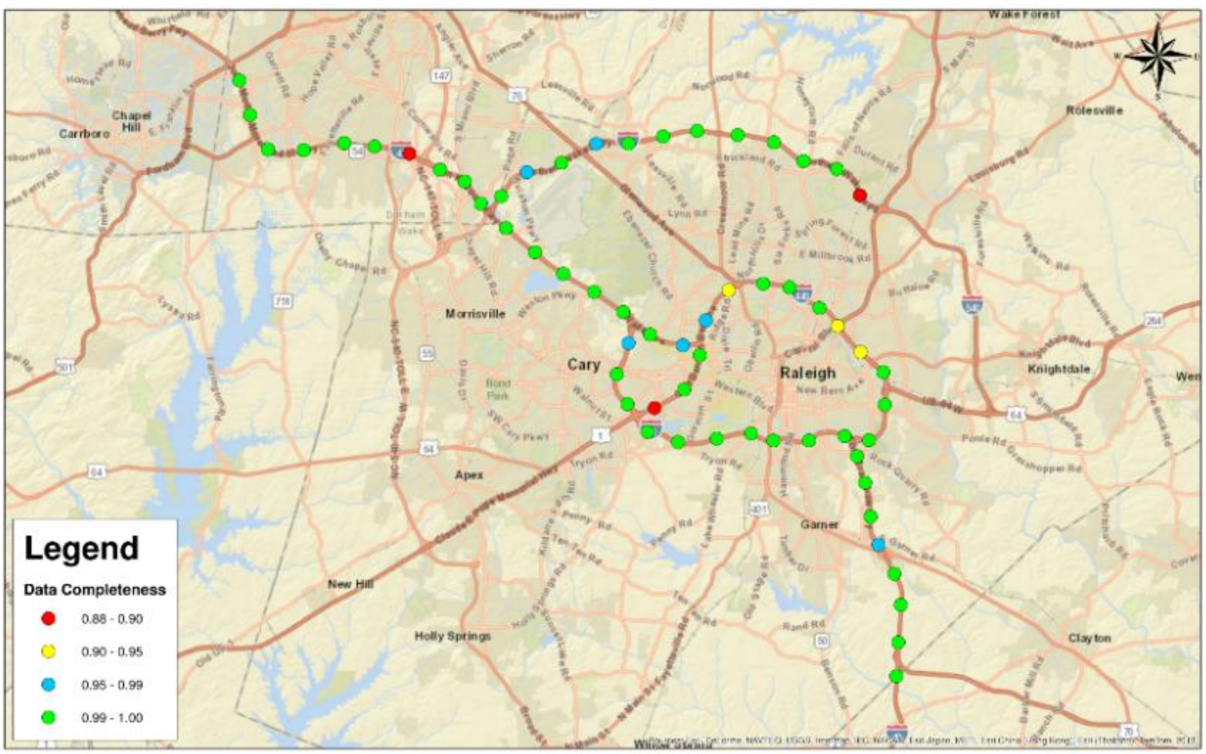
The research team explored the feasibility of using Here.com traffic sensor data for use in calculating the peak average daily traffic (PADT) factors for prioritization P5.0. Appendix C summarizes: 1) characteristics of data from HERE.com sensors; 2) the distribution of PADT factors; and 3) comparison between HERE.com calculated PADT factors and NCDOT count-based PADT factors/default factors.

Characteristics of Data from HERE.com Sensors

For this evaluation, the research team used 80 HERE.com sensors in Raleigh, NC to calculate PADT factors. These sensors are distributed along I40/I-440 and I-540. Prior to calculating PADT factors, the characteristics of the data were evaluated in terms of three aspects: 1) Data Completeness, 2) Potential Errors/Outliers, and 3) Data Coverage.

Data Completeness

Data completeness of a sensor is defined as the percentage of data available for the 12-month evaluation period. It is calculated by diving the available sample (all days and time periods) by the maximum feasible sample for that same duration. The following map demonstrates the performance of all HERE.com sensors in terms of data completeness between May 2012 and April 2013. As shown in the map, most sensors have more than 95% of data available during the 12-month period. Three detectors have less than 90% data available; data completeness for these sensors is between 88% and 90%. Overall, the HERE.com sensors provide an acceptable level of data completeness for the PADT factor evaluation.



Data Completeness of HERE.com Sensors

Potential Data Outliers
Potential data outliers are evaluated based on a typical statistical method. An observation is flagged as an outlier if it is outside the range:

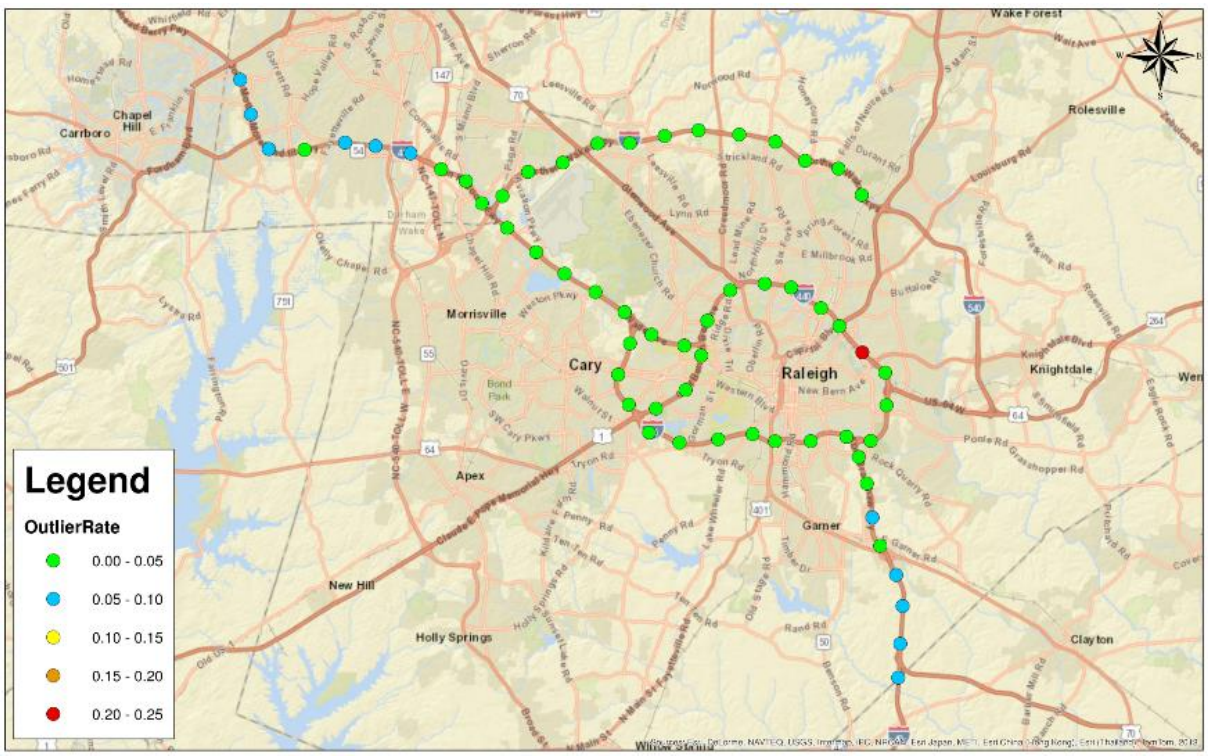
$$[Q1 - 1.5(Q3 - Q1), Q3 + 1.5(Q3 - Q1)]$$

Where,

Q1: the 25th percentile value

Q3: the 75th percentile value

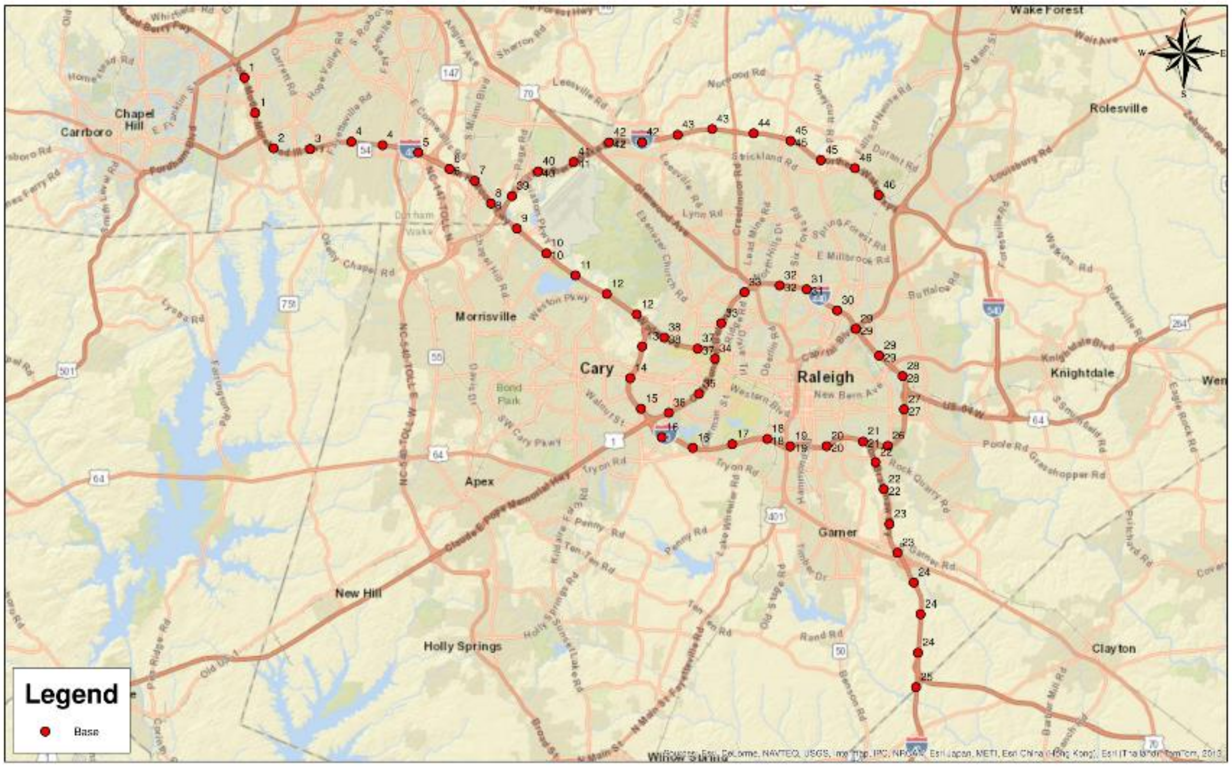
The following map shows the outlier rate of HERE.com sensors, which is calculated as the ratio of number of outliers to total available data observations. As shown in the map, most sensors have less than a 5% outlier rate. The sensors located towards the edges of the study area along I-40 show a consistent outlier rate between 5% and 10%. Given the consistency of these “outliers” across several adjacent sensor, this trend is attribute to a wider distribution of observations compared to other locations. These sensors still appear viable for evaluation of PADT factors, since given the consistency of observations, the effect is unlikely to be due to sensor malfunction or other data errors. One sensor on I-440 showed an outlier rate in excess of 20%. This sensor is the only one showing this trend, with adjacent sensors having less than 5% outliers. It is therefore deemed that this >20% outlier rate is likely to be due to sensor malfunction, and therefore it is not recommended to develop a PADT factor from this location.



Data Outlier Rate of HERE.com Sensors

Data Coverage
Data coverage is also very important for PADT factor calculation, defined as matching the sensor location with the segment ID used in the NCDOT prioritization process. High data coverage will improve the accuracy of PADT factor calculation by reducing the estimation error. The following map shows the data

coverage of HERE.com sensors. As shown in the map, the red dots are the sensor location and the numbers are the corresponding NCDOT segment IDs. A freeway segment is defined as the roadway between two adjacent interchanges. The sensors with same segment ID are located in the same roadway segment (i.e., between same interchanges). Within HERE.com system, except for four segments, every segment has at least one HERE.com sensor which could be used to calculate a PADT factor. In sum, HERE.com provides sufficient data coverage for the study area, with each segment having at least one sensor associated with it.



Data Coverage of HERE.com Sensors

Distribution of PADT Factors

With the 12-month data from the evaluated HERE.com sensors, PADT factors were calculated for each sensor location. For each sensor location, the monthly PADT factor is calculated as:

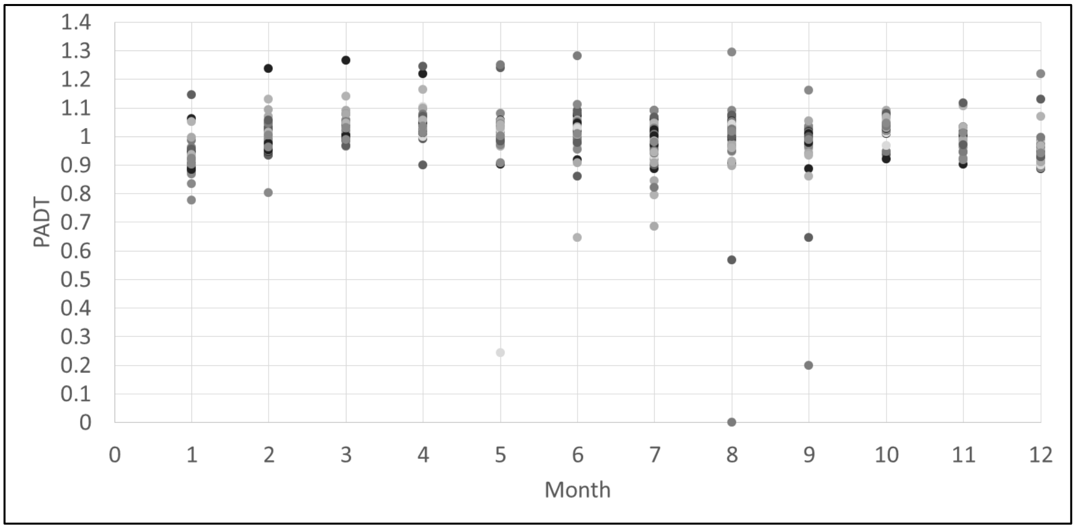
$$Monthly\ PADT\ factor = \frac{MADT}{AADT}$$

Where,

MADT: monthly average daily traffic

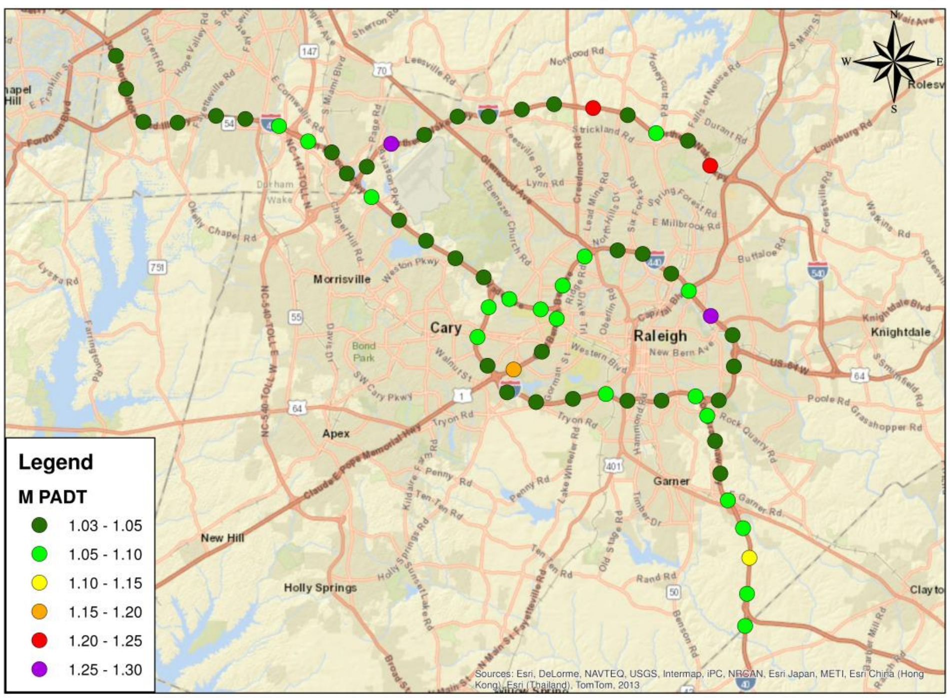
AADT: Annual average daily traffic

The following figure demonstrates the distribution of monthly PADT factors of HERE.com sensors. It is obvious that there are several outliers in the data within August and September. In general, the distribution of monthly factors clearly suggests that there is seasonal variability within study area and peak loads may occur in March and April.



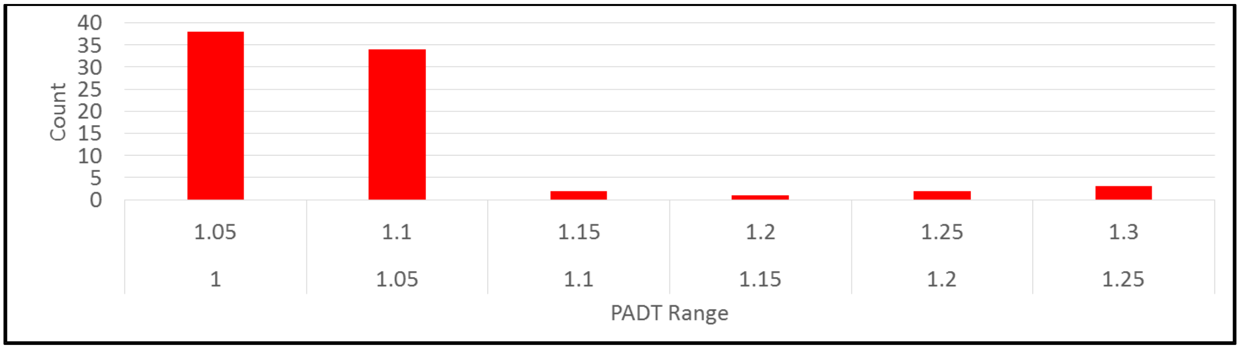
PADT Factors by Month

The following map shows the maximum monthly PADT factor of individual sensors within the study area. As shown in the map, there is obvious variability across different freeway segments in the study area, including a few "hot spots," which have high PADT factors in excess of 1.25. Note that one of the two high PADT location is the previously identified outlier sensor.



Maximum Monthly PADT Factors of HERE.com Sensor

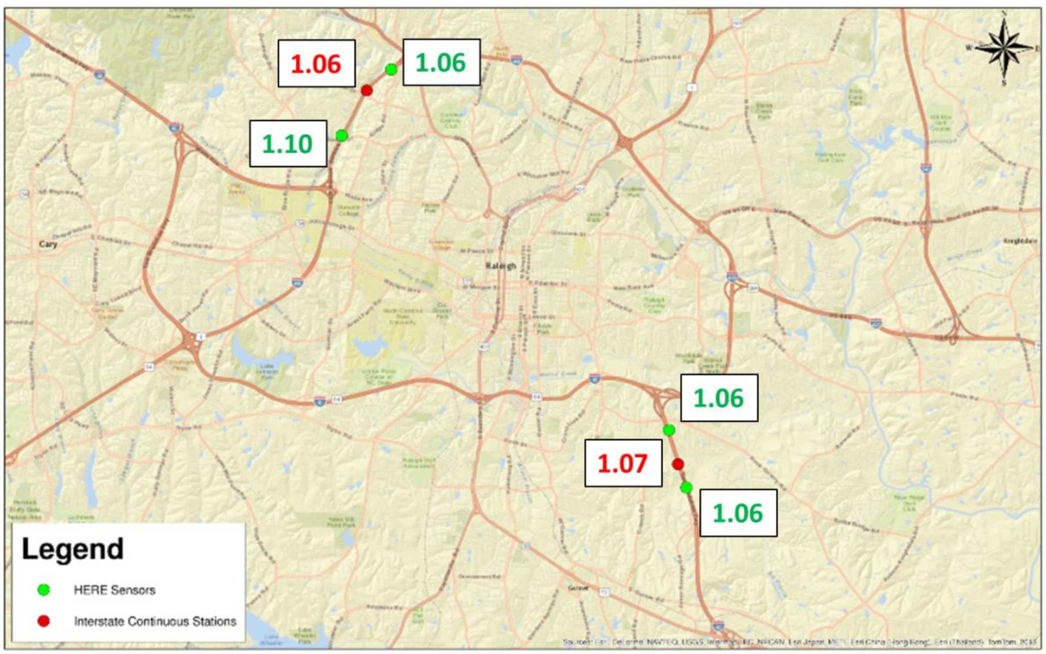
The following figure summarizes the distribution of maximum monthly PADT factors. More than 90% of HERE.com sensors suggest that PADT factors are less than 1.1, while eight locations show higher PADT factors.



Distribution of Maximum Monthly PADT Factors

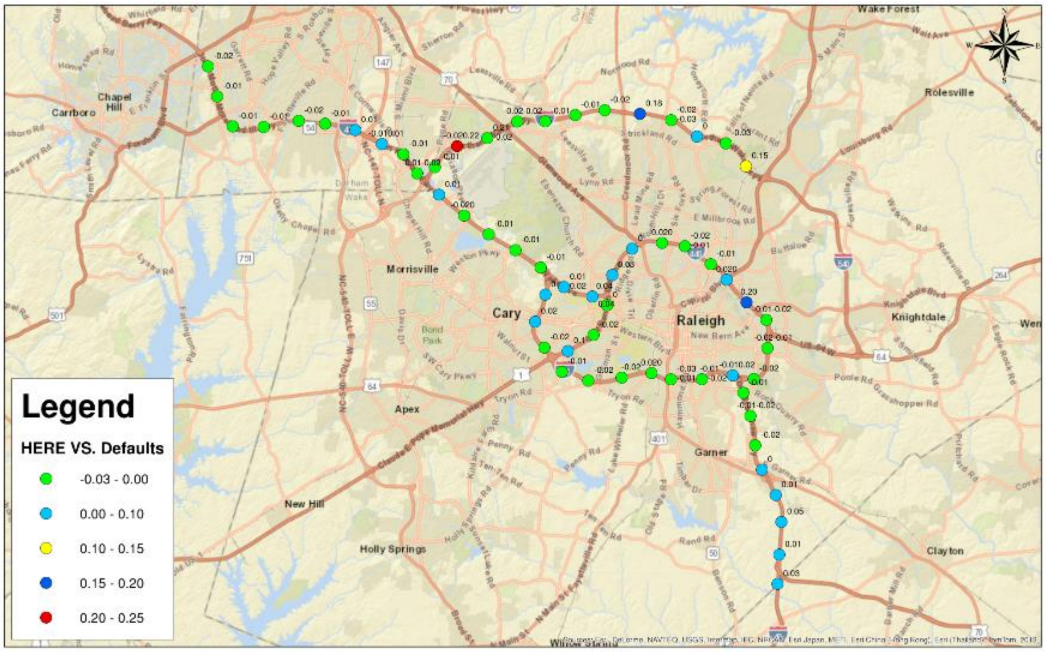
PADT Factor Comparison

In this section, the PADT factors calculated based on HERE.com sensors are compared with NCDOT count-based PADT factors and NCDOT default PADT factor values. There are only two interstate continuous stations within the area covered by HERE.com sensors. The following map shows the locations of interstate continuous stations and the corresponding nearby HERE.com sensors. The HERE.com sensor-based PADT factors match the two NCDOT count-based PADT factors well.



PADT Comparisons (HERE VS. NCDOT Count-based PADT)

The following map demonstrates the PADT factor difference between the HERE.com sensor-based PADT factors and the NCDOT default PADT factor values at the corresponding locations. As shown in the map, only four sensor stations show PADT factor differences (HERE.com sensor-based PADT factor - NCDOT default PADT factor) greater than 0.1. The other stations are within the (-0.03, 0.1) range.



PADT Factor Comparisons (HERE.com VS. NCDOT Default PADT Factor Values)

Summary

The feasibility of using HERE.com traffic sensor data in calculating peak average daily traffic (PADT) factors was determined by evaluating the data from HERE.com sensors and comparing their PADT factors with NCDOT count-based PADT factors and NCDOT default PADT factor values. In general, HERE.com sensors provide data with good quality with the following characteristics:

- HERE.com sensors provide a near complete sample of volume data: greater than 85% completeness and over 95% completeness for most sensors;
- HERE.com sensors provide accurate volume data: most sensors have less than a 5% outlier rate and only one station was flagged as a potential mal-function issue with more than 20% outliers;
- HERE.com sensors provide great data coverage: every segment has at least one HERE.com sensor which could be used to calculate a PADT factor.

Regarding the PADT factors, more than 90% of HERE.com sensors suggest that PADT factors are less than 1.1, while eight locations shows higher PADT factors. The HERE.com sensor-based PADT factors match the two NCDOT count-based PADT factors very well. Comparing with NCDOT default PADT factor values, only four sensor stations show PADT factor differences greater than 0.1, while the other stations are within the (-0.03, 0.1) range.